Upper Green River Basin Ozone Wind Field Investigation (O3w): Data Summary Report

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ABSTRACT

Under stagnant conditions, typical during periods of elevated ozone, local terrain-induced wind flow interacts with the synoptic flow to create patterns in the surface wind flow. Together, these flows determine the fate of regional elevated ozone concentrations. The Upper Green River Basin Ozone Wind Field Investigation (O3w) was a designed to characterize these surface wind patterns within the context of the basin's overall wintertime flow pattern climatology. During the field project, ten mesonet systems were deployed throughout the basin. Mesonet site locations were selected to form an expanded network of 15 sites that incorporated existing regulatory network stations. Location specific siting criteria determined whether the site observed general wind flow, or captured local terrain-induced wind flow. Wind speed, wind direction, and temperature were monitored continuously at all study sites between January 1st and March 31st, 2012. To ensure that Mesonet data quality was comparable to network data, an external audit of two sites was performed. Furthermore an internal audit of all Mesonet sites was performed at the end of the study. A summary of the data collected, as well as the results of both the external and internal audits are reported. All mesonet parameters meet the required performance criteria, so no calibration corrections were necessary during data validation. Procedures to ensure data quality, including Standard Operating Procedures (SOPs) for site selection, instrument calibration, equipment set-up, data collection, and data cleaning are included in the Appendix of this report.

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1.0 BACKGROUND

Sublette County, Wyoming, is perhaps best known by tourists and residents alike for its scenic landscape and outstanding outdoor recreational facilities. In the past, its low population enjoyed pristine air quality, but since the advent of oil and natural gas field development in the region, the rural character of the county has changed, as have the observed levels of air pollutants. Fifteen years ago, both air quality and meteorological data in Sublette County were limited to a select few sites—within the Bridger Wilderness Area, near the town of Pinedale, and local airports (Sisler and Malm, 2000; Baumgardner et al., 1999; Lamb and Bowersox, 2000)—and to occasional data from short-term experiments such as the 1995 airborne South-west Wyoming Visibility Study (SWYVIS) (Han et al. 2003.) Consequently, with such limited geographic coverage, a detailed appreciation of air pollutant distribution and surface wind flow patterns was precluded.

This coverage began to change in 2005 with the discovery of elevated ozone, which prompted the Wyoming State Department of Environmental Quality (WDEQ-AQD) to initiate coordinated air quality monitoring and modeling studies for the region. During the first observation period in the winter of 2005, ozone concentrations were observed to exceed the 8-Hour National Ambient Air Quality Standards (NAAQS) of 0.08 ppm (80 ppb) at both the Boulder, WY, and Jonah, WY sites, where maximum values of 89 ppb and 98 ppb, respectively, were observed (MSI et al. 2011). Subsequent monitoring throughout the county has confirmed that ozone exceedences have occurred on numerous occasions, and has led to the designation of Sublette County by the EPA as an area of "marginal nonattainment" for ozone pollution (EPA 2012).

Ozone is a secondary pollutant, produced photochemically in the atmosphere from precursor species, specifically the oxides of nitrogen (NO_x), which mainly come from combustion sources, and volatile organic compounds (VOC), which are emitted by a wide variety of sources, including fossil fuel extraction operations and vehicles. Consequently, since operations associated with the natural gas extraction industry are known to emit large amounts of NO_x and VOCs (U.S. DOI 2006), and since natural gas extraction is the largest industry in Sublette County, it must therefore be considered as a potential source of air pollutants. Since small oil and natural gas exploration projects commenced in the basin some 15 – 20 years ago, development has accelerated, particularly within the last decade, with project authorizations through BLM-Issued Records of Decision bring issued for more than 8,500 new wells in the Pinedale Anticline Project Area (PAPA), the Jonah Field II Project Area (J2PA), and the Jonah Infill Drilling Project Area (JIDPA) (U.S. DOI 2000, U.S. DOI 2006, U.S. DOI 2008).

The high winter-time ozone concentrations measured at WDEQ-AQD monitoring stations were entirely unexpected, primarily because episodes elsewhere were known to invariably occur during the summer months when high solar elevation angles lead to higher incident intensities of ultra-violet (UV) radiation, resulting in maximum ozone photochemical production rates (Nunnermacker et al., 1998; Vukovich et al., 1977). Analyses of the measurements from the WDEQ-AQD sponsored studies have identified the necessary conditions for the formation of high wintertime concentrations of ozone in this area. They include extensive snow cover; prevailing high pressure; light winds to prevent pollutant dispersion and dilution; and a strong,

shallow, surface-based, pollutant-trapping temperature inversion to promote high precursor concentrations (Schnell et al., 2009; Stoekenius and Ma, 2010). These synoptic conditions provide the context into which local-scale wind circulations form, and together, they help determine the fate of regionally elevated ozone cocentrations.

2.0 INTRODUCTION

The Upper Green River Basin (UGRB) is situated within Sublette County, Wyoming, along Wyoming's western border with Idaho, at an altitude of 2150m. The basin is bordered to the west by the Wyoming Range, which rises to an altitude of 11,378 ft., to the north by the Gros Ventre Range, and to the east and northeast by the Wind River Range, in which the tallest peak in Wyoming, Gannett Peak (13,804ft.), is located. These mountains border the basin on three sides, leaving the south side open to plains and the I-80 corridor. Prominent features within the UGRB include The Mesa, a plateau, which is elevated approximately 100m above the average basin altitude, and is bordered to the west by the Green River and to the southeast by the New Fork River. Local features are expected to play an important role in the surface wind flow, while the mountains surrounding the basin may affect its interaction with the typical regional weather patterns. It is the complex interactions between weather and terrain which produce the observed wind patterns within the basin.

Past research has shown that wind patterns induced by complex topography interacting with synoptic-scale winds affect the spatial distribution of air pollutants (de Foy et al., 2005; Fast and Zhong, 2008). This relationship between wind and pollution is a growing concern in the UGRB, especially since the EPA has recently designated the UGRB as an area with "marginal nonattainment" for ozone pollution (EPA, 2012).

Previous monitoring efforts within the basin have resulted in several observations in regard to these surface winds. These observations include mention of a diurnal wind shift, which recirculates pollutants within the basin during periods of elevated ozone (ENVIRON, 2008; Stoeckenius and Ma, 2010). Preliminary observations (Stoeckenius and Ma, 2010; MSI, 2011) also suggest that more than one wind flow pattern may indeed occur within the basin, as high ozone concentrations have been observed migrating to both the east and west of the mesa during the late afternoon and early evening hours; however, these patterns have yet to be systematically quantified or verified. Additionally, the observations hint at the existence of transient convergence zones along which pollutants are known to accumulate in similar high altitude basins (Jauregui, 1988; Kitada and Regmi, 2003; de Foy et al., 2005; Stoeckenius and Ma, 2010).

Although these monitoring efforts have made several important observations regarding the surface winds in the UGRB, the focus of these studies was on designating parameters that could be used to forecast periods of potentially elevated ozone, rather than specifically characterizing the wind flow within the basin. Consequently, the Upper Green River Basin Ozone Wind Field Investigation (O3w) was a targeted monitoring effort to characterize the wintertime surface wind flow in the basin. Each monitoring site location was selected by considering the locations of both the current and previous monitoring networks in the basin, the local terrain, and the site's potential to observe either the overall wind flow or the local terrain-induced wind flow. Several sites were also chosen because, as of 2011, no monitoring had yet been done in those locations.

This report provides an overview of the O3w project (Sect. 2.0), and describes the methodology, which contains a summary of the procedures used to ensure data quality (Sect. 3.0). These procedures, which include Standard Operating Procedures (SOPs) used for site selection, instrument calibration, equipment setup, data collection, and data cleaning, can be found in the

Appendix, which also includes the results of both the internal and external audits performed on the equipment. Section 4.0 describes the instrumentation used during the project, and Section 5.0 provides a summary of the data collected at each of the ten monitoring site locations.

3.0 METHODOLOGY

The O3w field project is a meso- to microscale wind monitoring effort for the UGRB in Sublette County, Wyoming for the purpose of characterizing wintertime surface wind patterns within the basin. During O3w, ten instrumented mesonet stations were deployed throughout the UGRB to measure wind speed, wind direction, and ambient temperature.

However, prior to deploying the mesonet, determining site locations that would adequately represent wind flow within the basin was paramount. Preliminary site selection was set by the distribution of existing sites and the understanding gained from both these sites, as well as previous monitoring projects (ENVIRON, 2008; Stoeckenius and Ma, 2010; MSI, 2011). Once suitable areas were selected, specific siting focused upon the local terrain. Site selection was further determined by whether the goal of that site was to observe the general basin wind flow or to capture local terrain-induced wind flow. After potential site locations were chosen, sites were then visited and the final site locations were chosen based on the on-location terrain and the criteria found in Section 2.0 of SOP 02. For some of these sites, permission had to be obtained from the landowners. Most sites were located on Federal land, and permission for these sites was given by the BLM.

3.1 Site Descriptions and Site Placement Rationale

While some mesonet systems were placed at locations that would experience weather conditions representative of the larger surrounding area, other systems were placed at locations that would reflect more localized wind flow. And to facilitate the aims of overall wind characterization, the overall site placement was dictated by an attempt to create a grid of semi-equally spaced weather stations within the context of current air quality and meteorological monitoring stations throughout the basin. A map of the ten mesonet site locations and their coordinates can be found in Figure 1 and Table 1. Following the figures are maps of the terrain around each site and the rationale behind each site's placement.

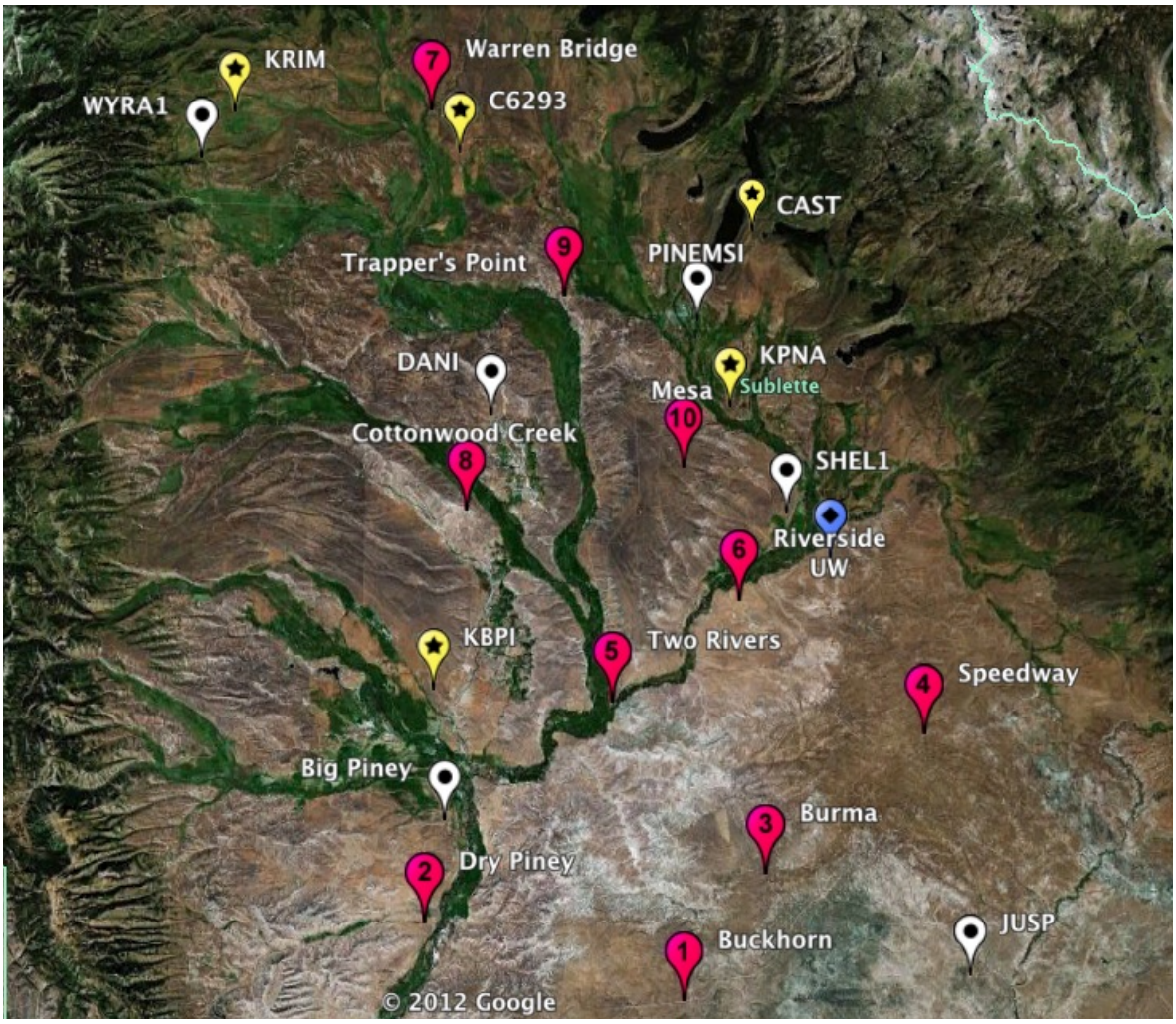


Figure 1: O3w site locations are numbered from 1 to 10, WDEQ continuous monitoring location are shown as white markers with circles, meteorological monitoring stations are shown as yellow markers with stars, and the UW Mobile Laboratory is shown as a blue marker with a diamond.

Table 1: Latitude and Longitude locations of Mesowest sites.

Mesonet Sites				
Site #	**Site Name**	**Latitude (°)**	**Longitude (°)**	**Elevation (m)**
1	Buckhorn	42.352	-109.854	2162
2	Dry Piney	42.410	-110.119	2058
3	Burma	42.448	-109.772	2161
4	Speedway	42.553	-109.611	2247
5	Two Rivers	42.577	-109.929	2092
6	Riverside	42.653	-109.801	2127
7	Warren Bridge	43.018	-110.119	2282
8	Cottonwood Creek	42.719	-110.079	2202
9	Trapper's Point	42.880	-109.981	2242
10	Mesa	42.752	-109.858	2284

Buckhorn: is located approximately halfway between Highways 191 and 189 on a slight incline that slopes up to the west, as seen in the topographical maps below. To the S/SE of this site is a smooth hill, or ridge, which is located more than twice as far away as the ridge is high. This means the ridge is far enough away that it should not immediately affect the wind at this site. The site is meant as a southern boundary site, and is on the edge of a possible recirculation path during periods of light winds.

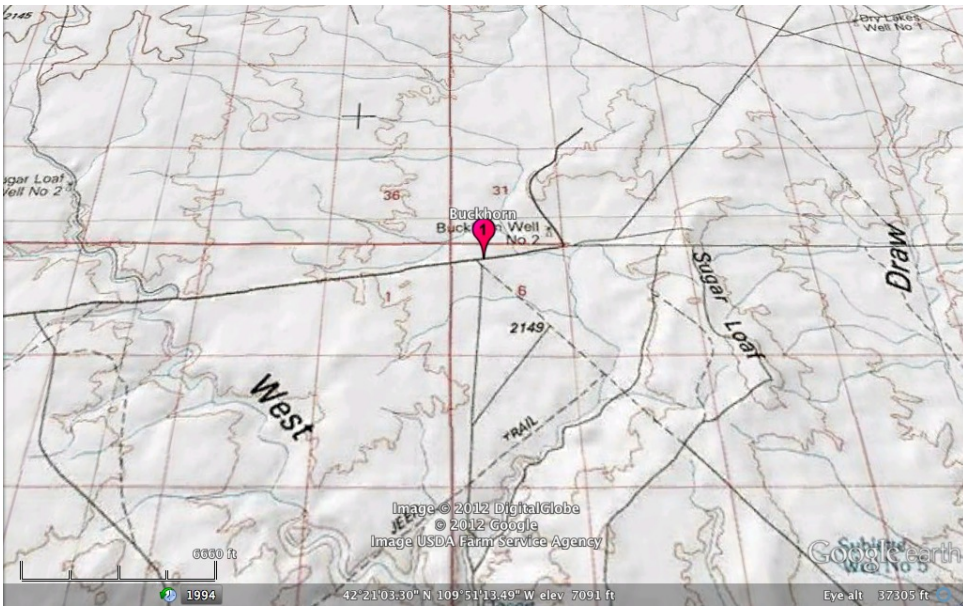
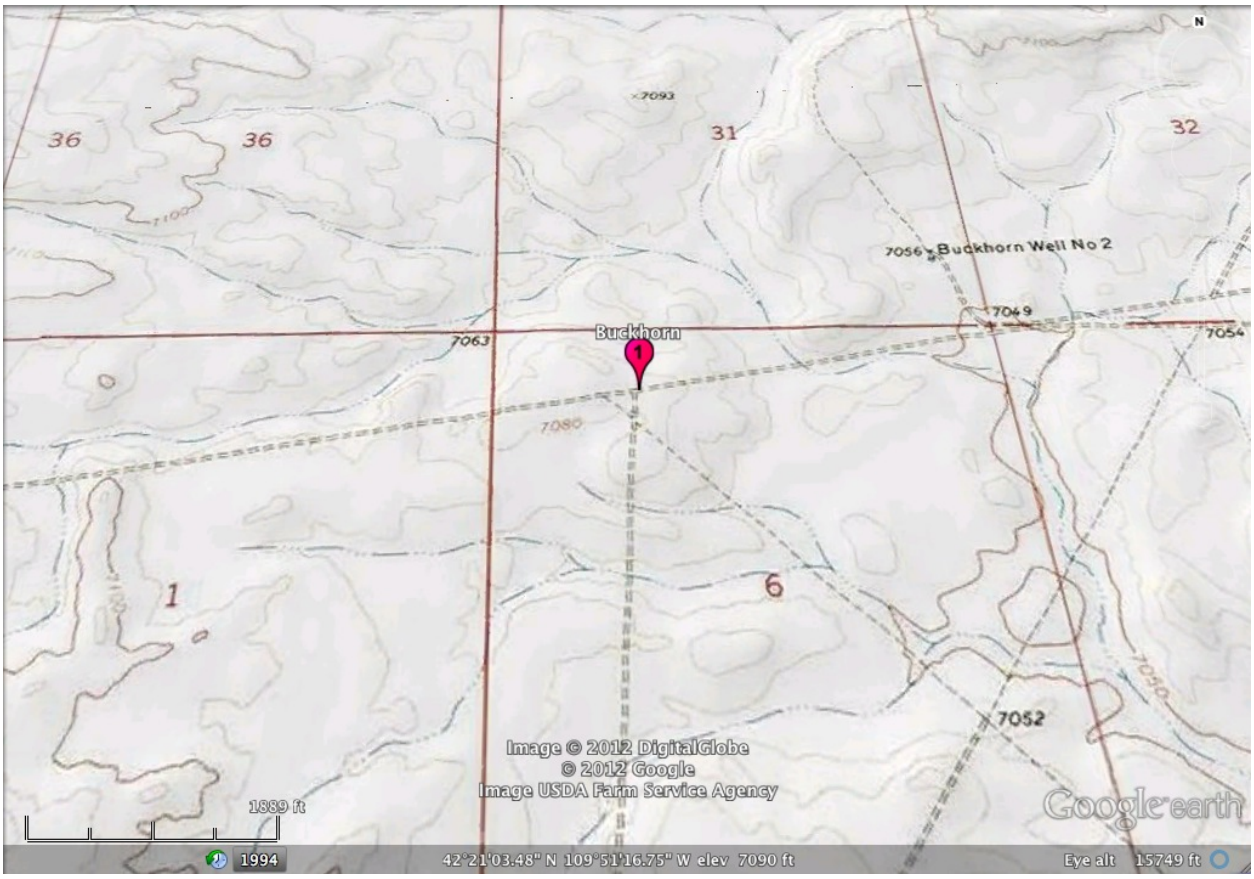


Figure 2a (left): The Buckhorn site at an eye altitude of 37305 ft.

Figure 2b (below): The Buckhorn site, zoomed to an eye altitude of 15749 ft. Each grid box represents one square mile.

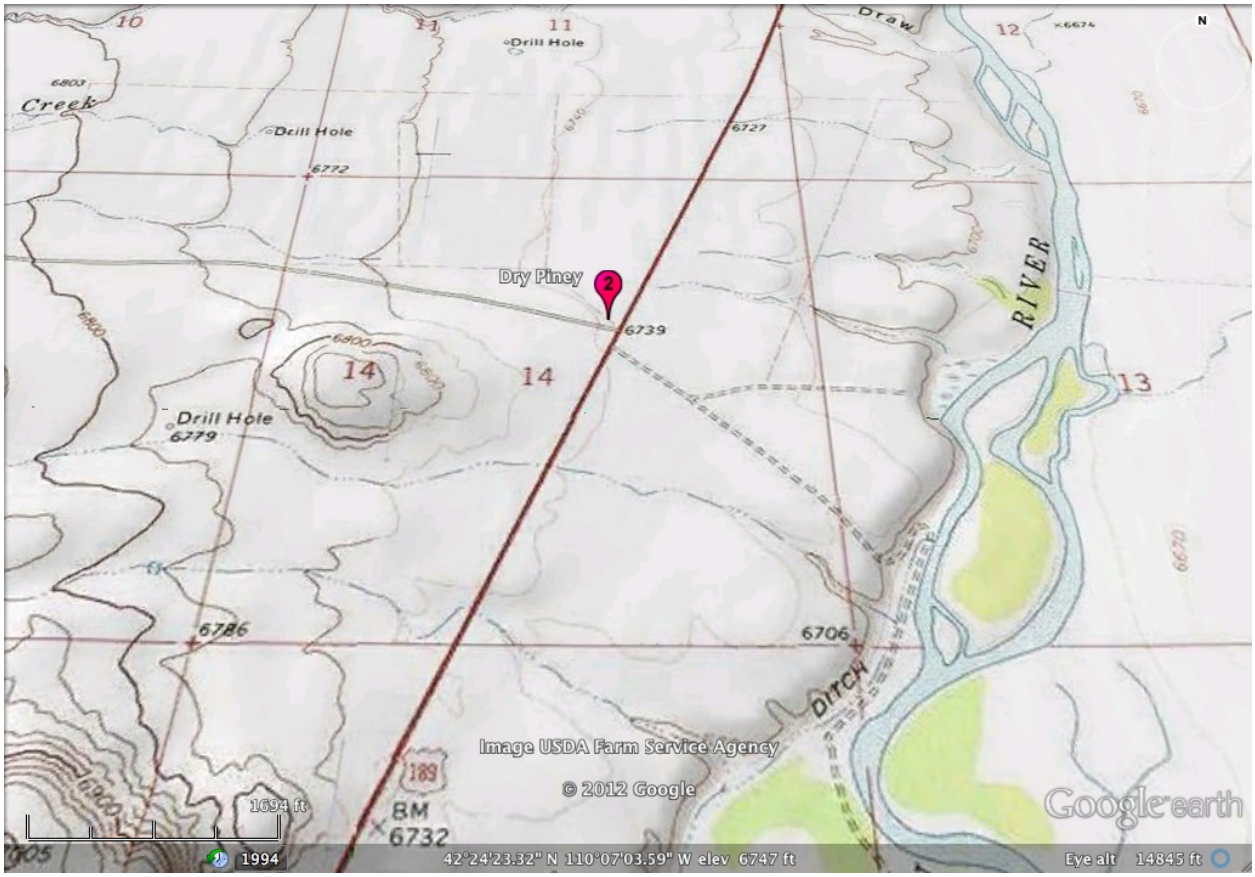


Dry Piney: is located on flat terrain near an informational BLM kiosk next to Highway 189. The Green River valley stretches from north to south within 1km to the east of the site. The purpose of this site is to capture the wind flow near the river valley, but a hill south of the site, as seen in Figure 3b, may have had an influence on winds from the southwest.

Figure 3a (left): The Dry Piney site at an eye altitude of 27270 ft.

Figure 3b (below): The Dry Piney site, zoomed to an eye altitude of 14845 ft.

Each grid box represents one square mile.

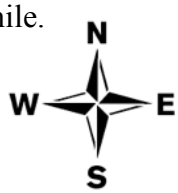


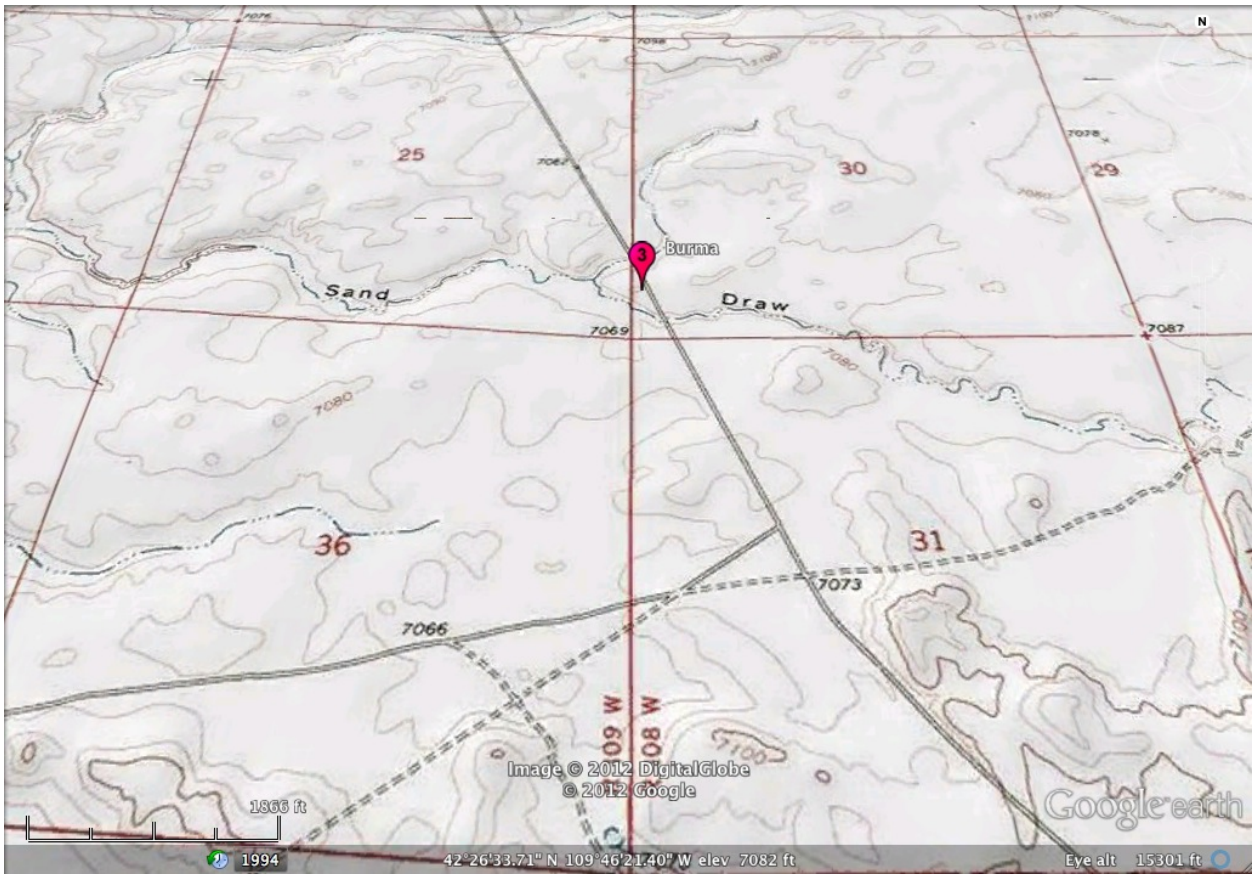
Burma: is located on the west side of Burma Road. The terrain is flat, although a few km to the south is a Yellow Point Ridge, as seen in Figure 4a. This site was placed in a location that had not been monitored in previous studies, and is near the western edge of the Jonah development.

Figure 4a (left): The Burma site at an eye altitude of 37305 ft.

Figure 4b (below): The Burma site, zoomed to an eye altitude of 15301 ft.

Each grid box represents one square mile.





Speedway: is located on the east side of Highway 191 on a small hill. This site was placed on a hill because the site is meant to represent the overall wind flow on the east side of the UGRB, so a location slightly elevated above the surrounding terrain was preferred.

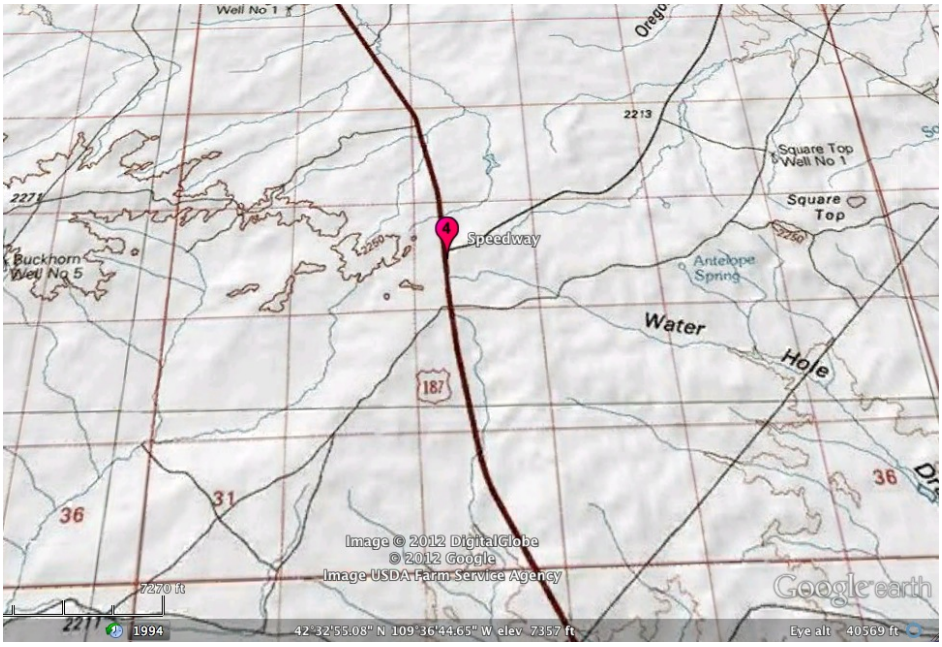
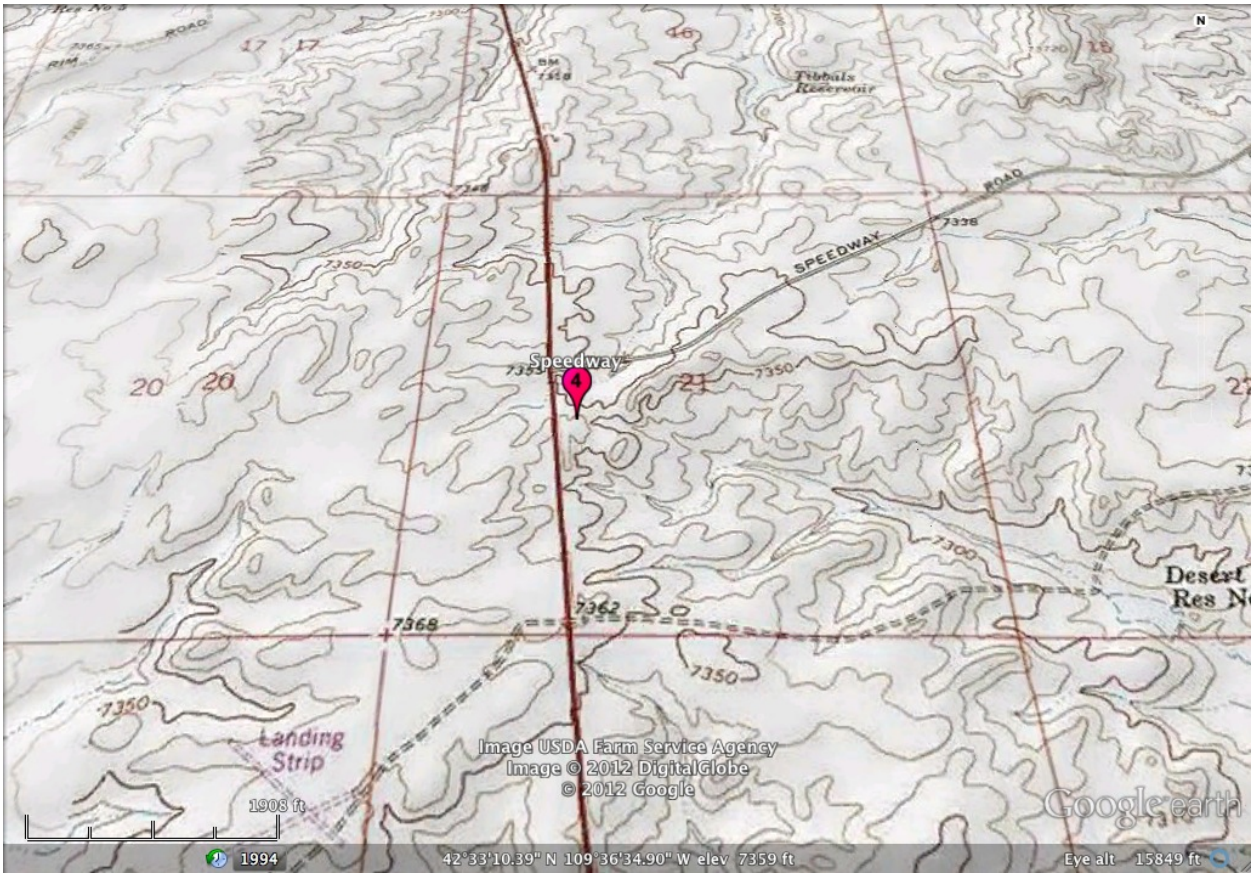


Figure 5a (left): The Speedway site from an eye altitude of 40569 ft.

Figure 5b (below): The Speedway site, zoomed to an eye altitude of 15849 ft.

Each grid box represents one square mile.



Two Rivers: is located on the property of Mr. John Linn, a Sublette County Commissioner, at the southernmost tip of the Mesa near the junction of the New Fork and Green River valleys. To the south, across the river, is Ross Butte, as seen in Figure 6a. We presumed that under stagnant conditions, the flow from the north would generally be blocked by the mesa, and that slope and valley flows, as well as channeling effects, would have a large influence on this site. This site is well-poised to experience flow within the New Fork River valley, which flows from NE to SW to the south of the site, and occasionally the flow from the Green River valley, which flows north to south to the west of the site.

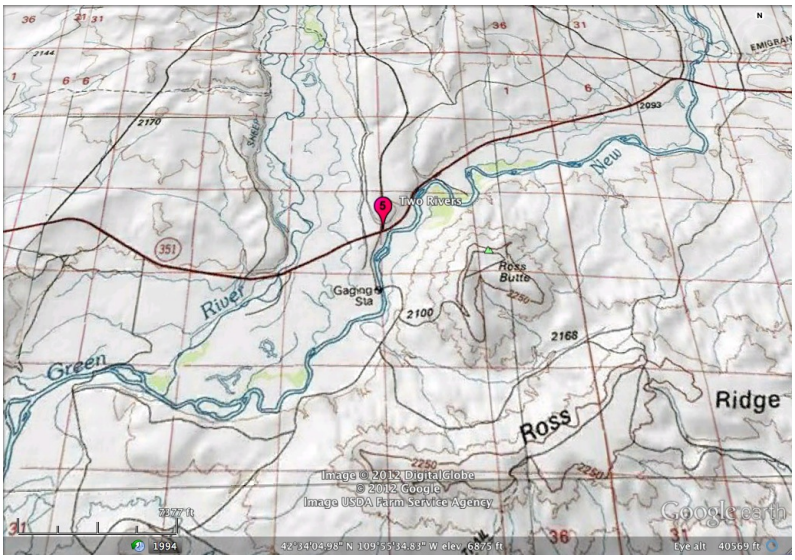
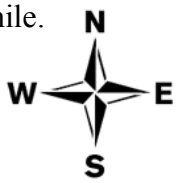
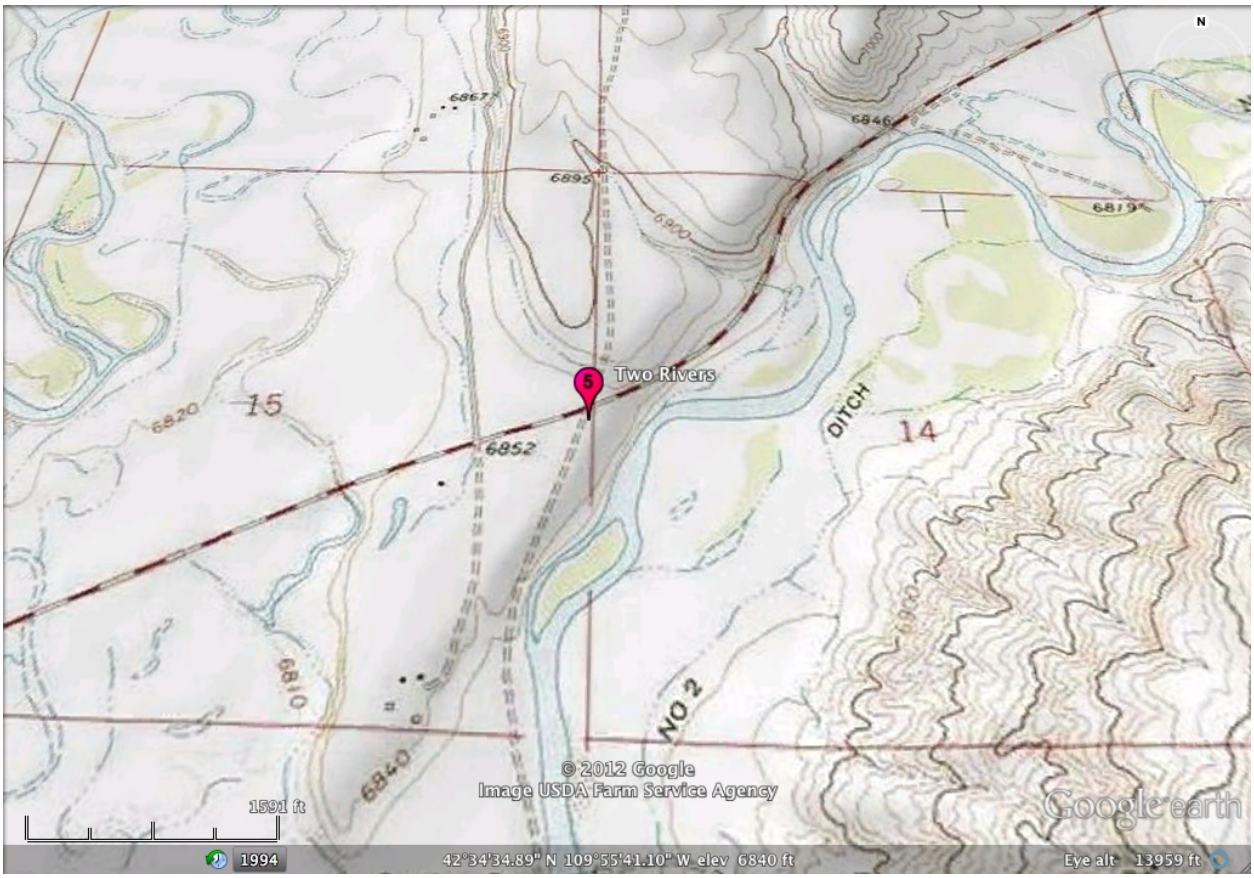


Figure 6a (left): The Two Rivers site from an eye altitude of 40569 ft.

Figure 6b (below): The Two Rivers site, zoomed to an eye altitude of 13959 ft.

Each grid box represents one square mile.



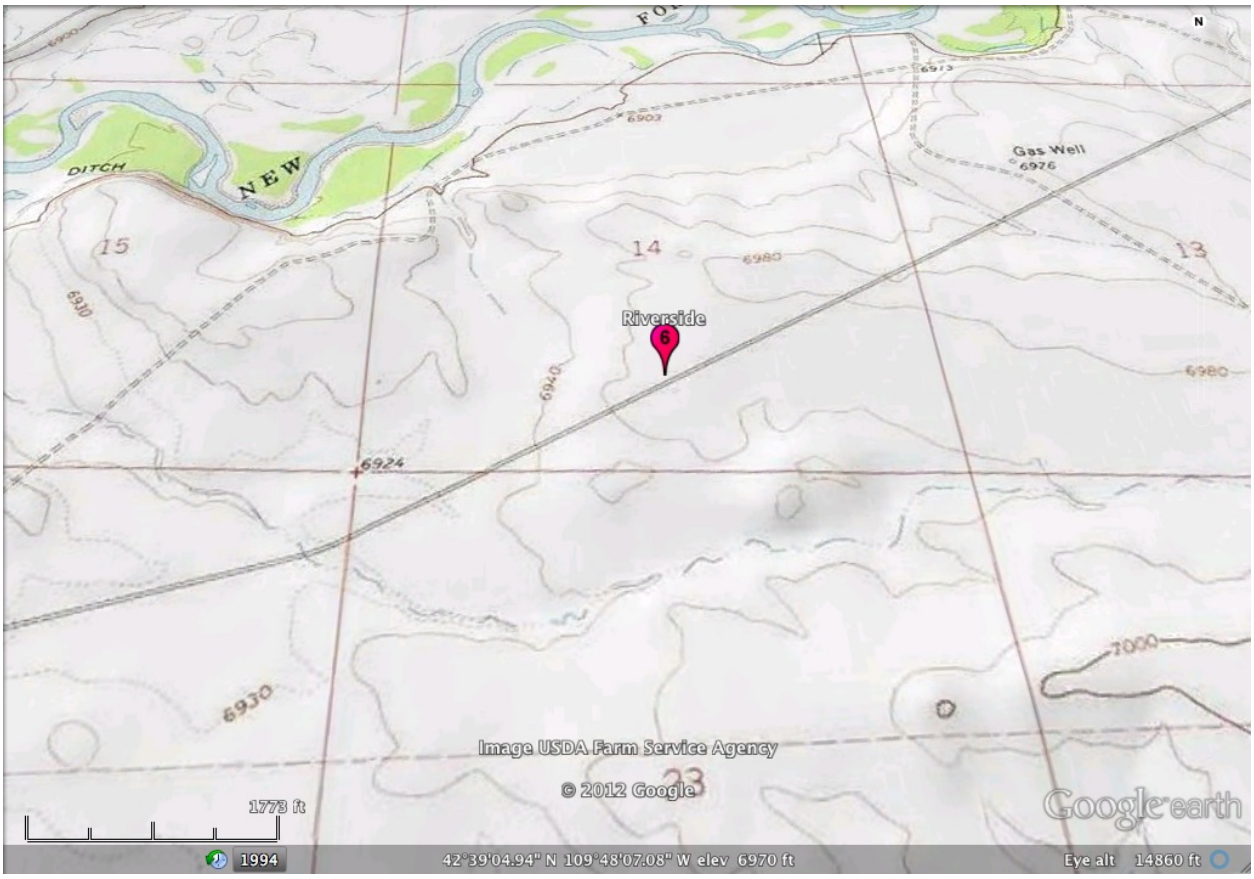


Riverside: is located just to the south and above the New Fork River Valley on Boulder South Road. The terrain is flat in the immediate vicinity, but to the north the terrain slopes down into the river valley, as seen in Figures 7a and b. Several km to the north of this site, across the river lays The Mesa. This site is located above the river valley so that it will be representative of a wider area and be less influenced by the local drainage flow experienced by previous monitoring efforts, which placed sites within the valley.

Figure 7a (left): The Riverside site from an eye altitude of 51145 ft.

Figure 7b (below): The Riverside site, zoomed to an eye altitude of 14860 ft.

Each grid box represents one square mile.



Warren Bridge: is located at the campground on the south side of the Green River as it crosses under Highway 189. The bridge itself is just to the northeast of the site, and nearby to the south is a hill, as seen in Figure 8b, which may affect wind flow. Under stagnant conditions, there is the potential for drainage flow at this location. This site is the northernmost boundary site.

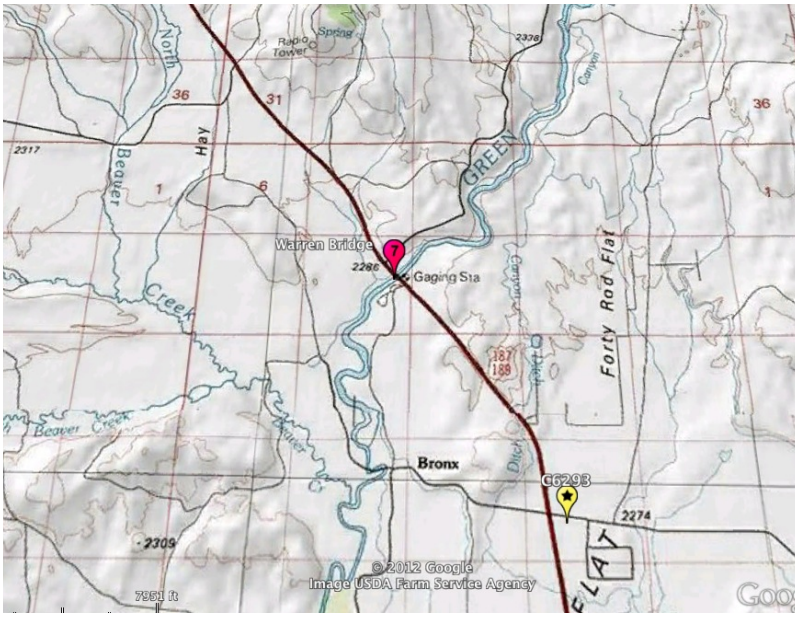
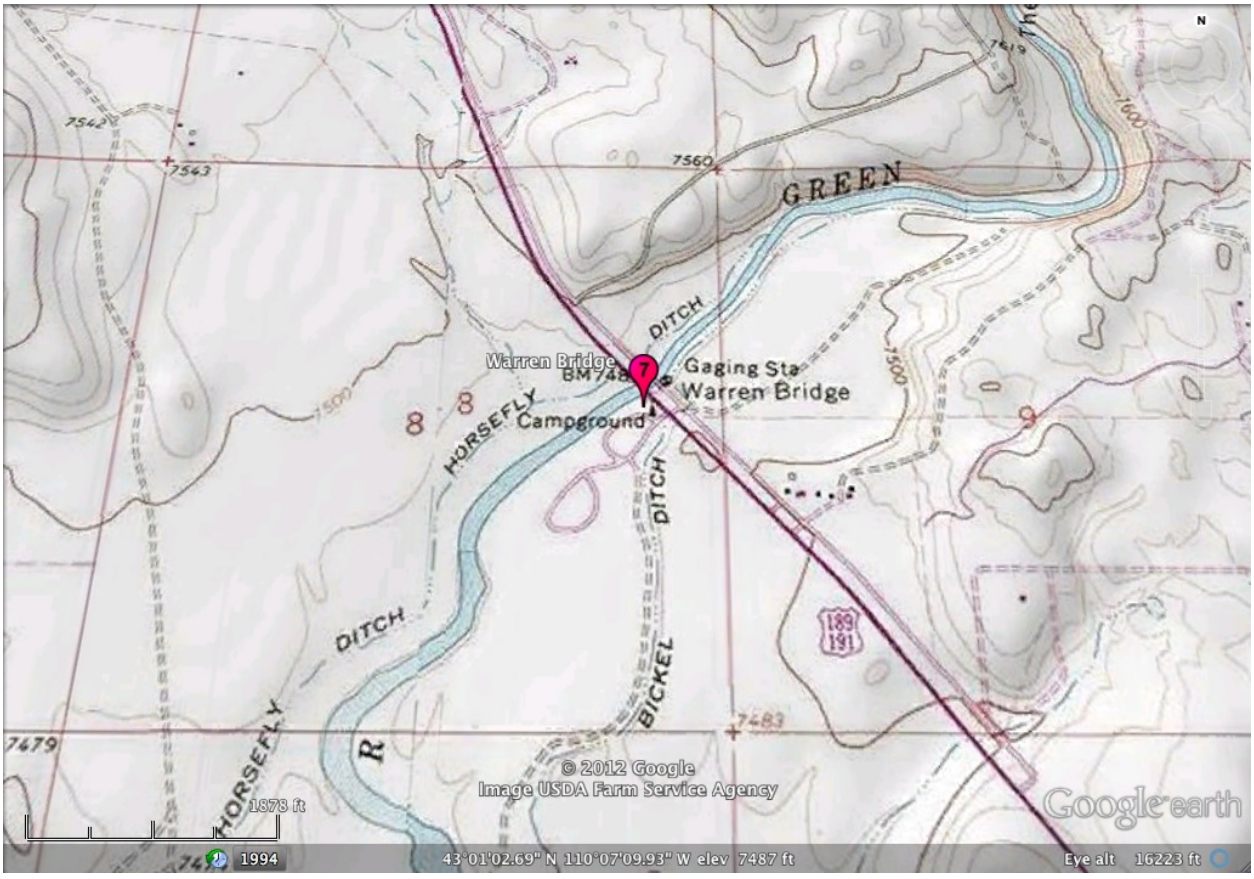


Figure 8a (left): The Warren Bridge site from an eye altitude of 44281 ft.

Figure 8b (below): The Warren Bridge site, zoomed to an eye altitude of 16223 ft.

Each grid box represents one square mile.

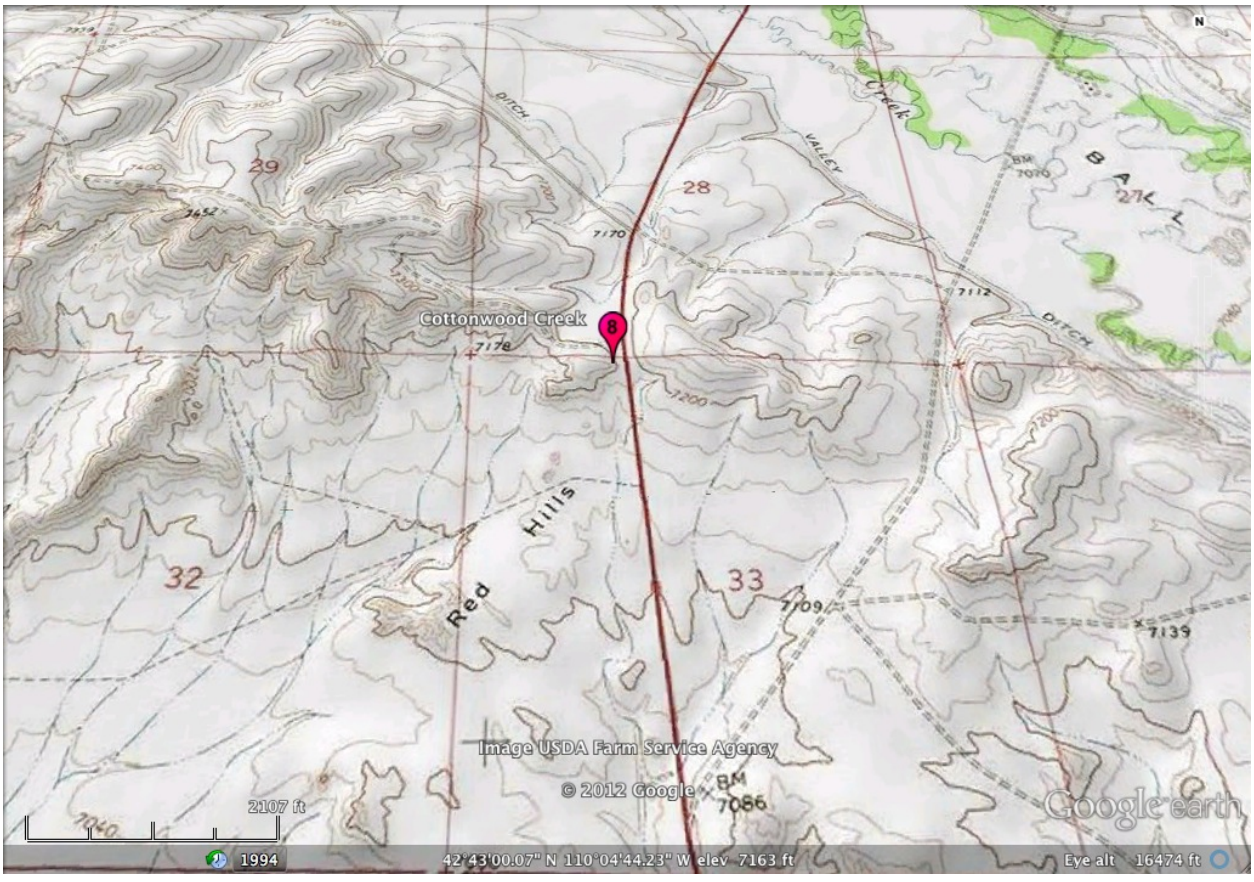


Cottonwood Creek: is located on a ridge of hills that stretches from west to east across Highway 189, which runs from north to south immediately east of the site, as seen in Figures 9a and 9b. Much further east of this site is The Mesa, which cannot be seen in the figures. From the site location, the terrain slopes steeply down toward the road. Previously, only one monitoring location, the WDEQ-AQD Daniel site, has been present to the west of The Mesa, so this site was placed at this location to test the current site's representativeness of the wind flow on the western side of the basin.

Figure 9a (left): The Cottonwood Creek site from an eye altitude of 39150 ft.

Figure 9b (below): The Cottonwood Creek site, zoomed to an eye altitude of 16474 ft.

Each grid box represents one square mile.

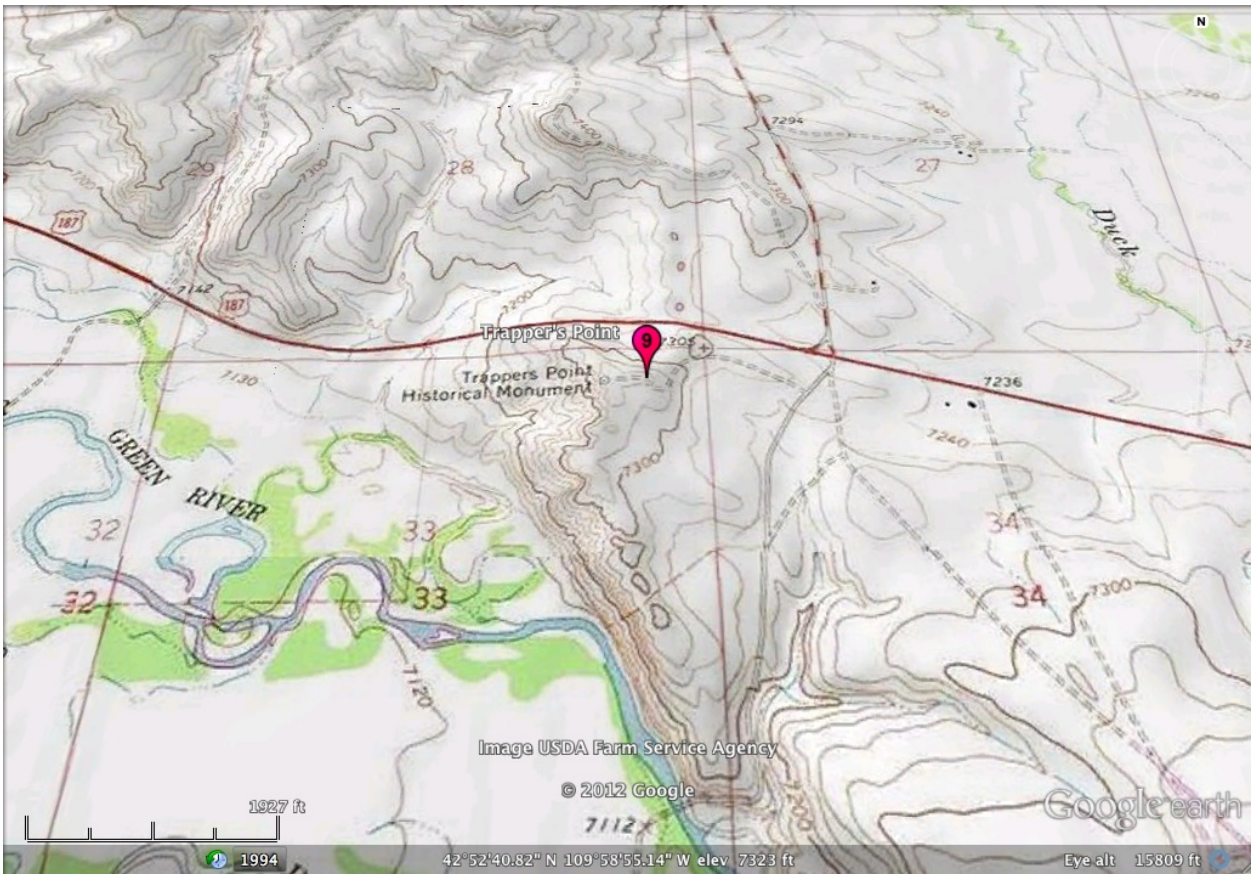


Trappers Point: is located on a hill at the northernmost point of The Mesa. This is a stand-alone hill, as can be seen in Figure 10b. To the west of the hill is the Green River valley, and to the north of the hill is Highway 191. This site is not located at the very top of the hill, due to historical site preservation; however, there was a flat area very near the top of the hill on which the site was placed. Because it is located on a large hill, this site is representative of the overall wind flow in the area.

Figure 10a (left): The Trappers Point site from an eye altitude of 32502 ft.

Figure 10b (below): The Trappers Point site, zoomed to an eye altitude of 15809 ft.

Each grid box represents one square mile.



Mesa: is located as close to the center of the Mesa as possible to be representative of the wind flow over The Mesa. The immediate terrain is flat, as can be seen in Figures 11a and b. Two drill rigs were located within 1km of this site throughout the study period.

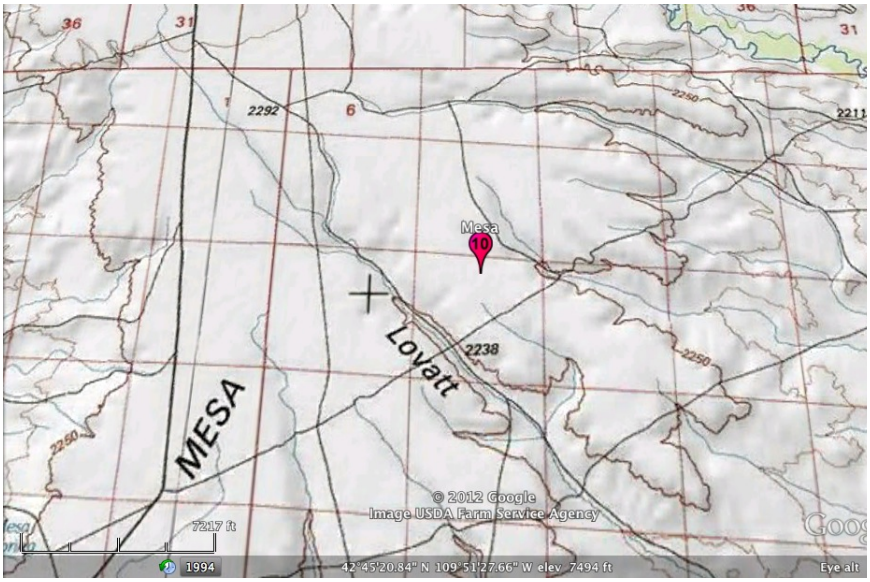
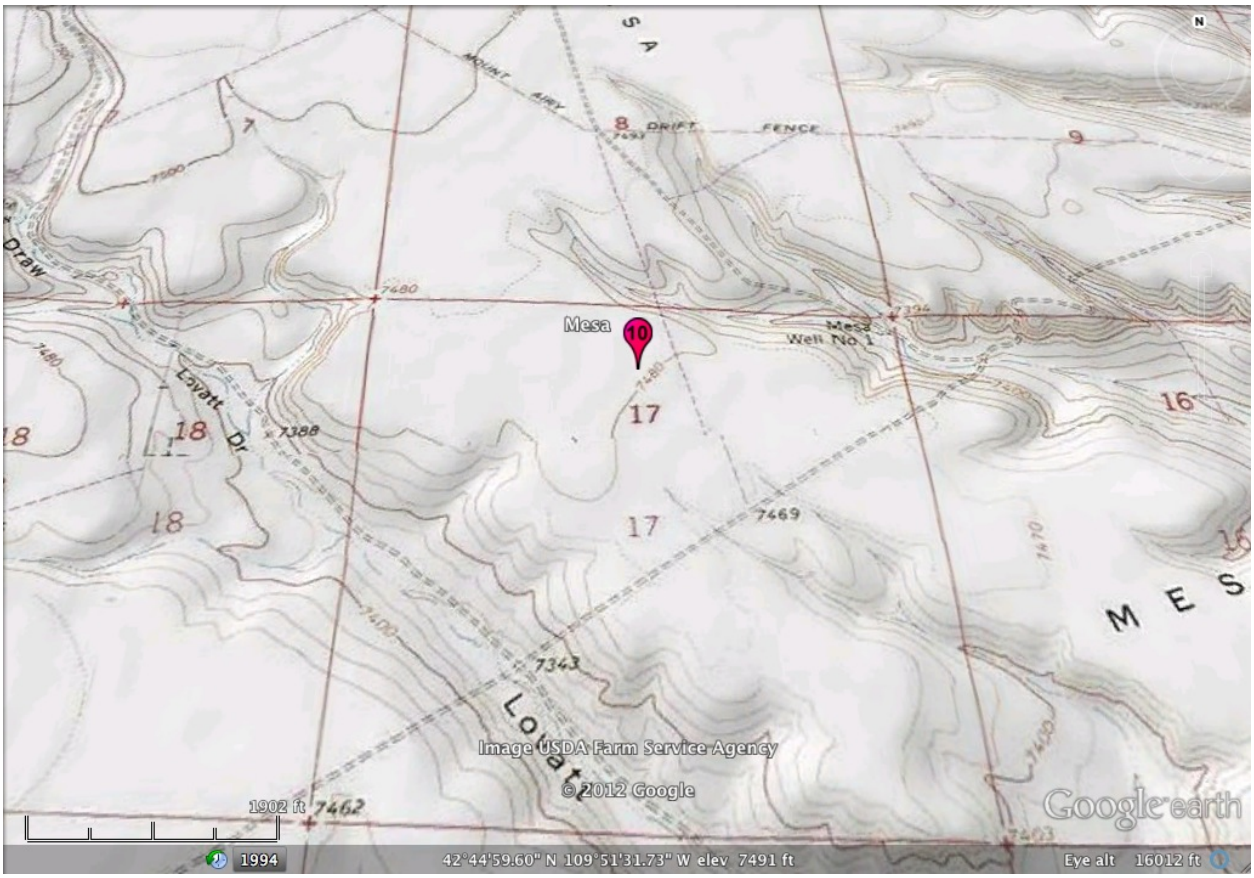


Figure 11a (left): The Mesa site at an eye altitude of 40575 ft.

Figure 11b (below): The Mesa site, zoomed to an eye altitude of 16012 ft.

Each grid box represents one square mile.



3.2 Pre-Deployment

The equipment and mesonet systems for this field project were loaned from the WDEQ-AQD, and additional equipment and software were purchased to facilitate data collection and instrument programming, namely a laptop computer, an RS232 to USB adapter cable, an RF401 Spread-Spectrum Radio, and Campbell Scientific PC400 software. All mesonet instruments were calibrated according to SOP 01, and the ten mesonet systems were assembled as a pre-deployment test of equipment integrity. Radio communication between select dataloggers and the field laptop were also established prior to instrument deployment so that data could be downloaded where direct physical access to the mesonet system would be difficult. With a clear line of sight, data could be downloaded from up to a mile away using radio telemetry.

3.3 Deployment

In mid-November, seven mesonet systems were brought to Sublette County and deployed to their respective sites, following the directions specified in SOP 02. The final three were deployed in mid-December. Deploying the instruments prior to the January 1, 2012 project start date was to field test the instruments and to troubleshoot any issues before they could affect the project dataset.

3.4 Data Collection

Once the mesonet systems were deployed, instrument data needed to be collected once every two weeks for systems with CR206 dataloggers, and once a month for systems with CR850 dataloggers, due to their much larger data storage capability. Data were collected by physically traveling to each site location, then downloading data by either connecting the field computer to the datalogger itself, or using the RF401 to communicate with the datalogger via radio telemetry. More specific instructions for how the data were collected can be found in SOP 03.

3.5 Audits

During the project, an external audit was performed by the WDEQ-AQD on the mesonet systems at Speedway and Riverside. We requested that an audit be performed on one of each of the two system types (the CR206, and the CR850 systems) to ensure that the instruments of each type were performing to the proper standard. All instruments performed within the quality standards specified in Table 2, meaning that no data transformations were needed. The audit results can be found in Section A2 of the Appendix.

Data were collected through mid-April, with the last site being taken down on April 11th. An internal audit was performed on the instruments before they were dismantled and placed in storage. A summary of the internal audit can be found in Section A3 of the Appendix. As with the external audit, all instruments performed within the quality standards specified in Table 2, meaning that no data transformations were necessary.

3.6 Data QA/QC

Once all data were collected, it was important to properly quality assure the data prior to analysis. Data quality assurance/quality control (QA/QC) involves omitting irrelevant data values, such as those taken during setup and takedown of the mesonet systems; resetting the time stamps so they conform to the time on the field laptop; flagging and omitting audit values; and interpolating missing data for periods less than 5 minutes long. SOP 04 details the steps followed in QA/QC of the data.

4.0 INSTRUMENTATION

Equipment for a complete mesonet system includes a 3-meter tall tripod to mount the equipment; a datalogger for data storage; a solar panel and a 110 amp-hour deep cycle 12-Volt battery to power the system; an instrument box or 100-gallon cooler to house the datalogger and battery; and wind and temperature instruments to monitor weather conditions.

Two sets of instrumentation were used as mesonet systems during O3w; one set used slightly older technology, which included CR206 dataloggers, RM Young model 05305-AQ wind monitors, and 109-L temperature probes (these will be known as CR206 systems), while the newer systems used CR850 dataloggers, RM Young model 05103 wind monitors, and 107-L temperature probes (these will be known as CR850 systems). Each of these instruments is described below, and all SOPs for their proper inspection, calibration, and installation can be found in Section A2 of the Appendix. CR206 systems were used at the Burma, Speedway, Two Rivers, Cottonwood Creek, and Trappers Point sites, and CR850 systems were used at the Buckhorn, Dry Piney, Riverside, Warren Bridge, and Mesa sites (Table 1).

4.1 RM Young Model 05305-AQ Wind Monitor

The 05305 Wind Monitor-AQ is a light-weight, high-performance wind-speed and wind-direction sensor designed specifically for air-quality measurements. Manufactured by R. M. Young, this sensor is cabled for use with Campbell Scientific dataloggers. The wind speed sensor for all the Wind Monitors is a helicoid-shaped, four-blade propeller. Rotation of the propeller produces an AC sine wave that has a frequency directly proportional to wind speed. It also uses a potentiometer to measure wind direction (www.campbellsci.com). Because of its low starting threshold for wind speed, this instrument can measure wind speeds from 0 to 50m/s. It can also operate in temperatures ranging from -50°C to 50°C, assuming non-riming conditions. See Table 2 for monitoring quality objectives for this instrument.

4.2 RM Young Model 05103 Wind Monitor

The 05103 Wind Monitor is a standard R.M. Young sensor for measuring horizontal wind speed and direction. Like the 05305, which is a high performance version of this standard monitor, the 05103 measures wind speed using a helicoid-shaped propeller, which produces a sine wave signal with frequency proportional to wind speed. Being more rugged than its counterpart, the 05103 can measure wind speeds from 0 – 100m/s

and operate in temperatures ranging from -50°C to 50°C, assuming non-riming conditions. See Table 2 for monitoring quality objectives for wind speed and direction measurements.

Table 2: Monitoring quality objectives for meteorological parameters

Horizontal Wind Speed	± 0.25m/s for ws ≤ 5m/s ± 5% for ws > 5m/s
Horizontal Wind Direction	± 5º
Propeller Torque	< 1gm-cm
Directional Torque	≤ 11 gm-cm for 05305-AQ ≤ 20 gm-cm for 05103
Temperature	≤ 1ºC

4.3 Model 109-L Temperature Probe

The Model 109-L Probe uses a BetaTherm 10K3A1 Thermistor to measure temperature. It is designed for use with CR200(X) series dataloggers. The probe has a temperature range of -50°C to +70°C and a maximum error of ±0.6°C over the operating range. Table 2 shows the monitoring quality objectives for temperature measurements. The time constant in air for the model 109-L probe is between 30 and 60 seconds in a wind speed of 5 m s^-1. This study recorded 1-minute, 5-minute, 60-minute, and daily averages.

4.4 Model 107-L Temperature Probe

The Model 107-L probe uses a BetaTherm 100K6A thermistor to measure temperature. The probe has a range of -35°C to +50°C and has a maximum error of <±0.5°C over the measurement range. Table 2 shows the monitoring quality objectives for temperature mesasurements.

4.5 Campbell Scientific RF401 Spread-Spectrum Radio

Data from CR206 dataloggers was accessed remotely using a Campbell Scientific RF401 Spread-Spectrum Radio. Using this instrument connected to a laptop computer and an omnidirectional antenna, mesonet dataloggers can be reached from up to a mile away, given a clear line of sight.

5.0 RESULTS

This section provides 1-page summaries of the data collected at each site. But first, Table 3 provides an overview of the important dates and time periods for each site, such as project start time, project end time, missing time periods, and times where measurement data were unavailable because of auditing.

5.1 Data Summary Graph Interpretation

Basic statistics for each parameter measured: wind speed, wind direction, and temperature, are given in Table a. on each site's data summary page. Figure b. is a wind rose for the given station, showing the percentage of time that the wind blew from each direction for wind speeds between 0 – 0.5m/s, 0.5 – 1 m/s, 1 – 2m/s, 2 – 4m/s, 4 – 8m/s, and 8m/s and above. Figures c. and e. are box and whisker plots of the diurnal variation in wind speed and temperature, respectively. The box contains the lower and upper quartiles (25% and 75%), while the whiskers include all the values within up to 1.5 times the interquartile range either above or below the median value. The median value is shown by a thick line within the box, and an open diamond indicates the mean value. Figure d. displays mean wind direction by hour of the day. Since wind direction has an intrinsic range of 0 to 360 degrees, it was not useful to display the quartiles, as was done in Figures c and e. Table f displays the rate of data capture, as well as the amount of data that were lost or affected due to instrument or wiring malfunction, auditing, or resetting the datalogger clock time.

5.2 Data Summary

Overall, there were several features seen in the data that occurred at most, if not all ten mesonet sites. Diurnally, each site typically experienced the highest wind speeds in the mid-afternoon, a morning wind shift that generally occurred between 8:00 and 12:00, and temperatures that are a minimum just before the sun rises around 7:00, and are highest around 15:00, soon after the sun is at its highest point in the sky. Because of the morning wind shift and highest wind speeds occurring in the afternoon, at some sites' wind roses, there is a contrast between the direction of the maximum frequency of high wind speeds and the direction of the maximum frequency of low wind speeds. The difference between high and low wind speeds where this contrast in wind direction can be seen is typically around 2 m/s, though this is not a hard and fast rule. Note that in the following sections, when I refer to a wind direction "quadrant", I am referring to the 90 degree range surrounding that particular direction. For example, the northwest quadrant refers to the range of directions from 270° to 360°. Each station lists a rate of data capture; however, all stations will have two missing data points, which have to do with the hour of missing data that is inherent in the switch from Mountain Standard Time (MST) to Mountain Daylight Time (MDT) that occurred on March 11.

Table 3: O3w Important Dates and Times

QA Code	Code Definition
aud	Audit
Start	Begin Data collection
End	End Data collection
rt-int	Reset Date/Time
dst	daylight savings time
wc-wd	faulty wiring connection-wind direction
wc-ws0	faulty wiring connection-wind speed is 0m/s
md	Missing Data
md-dl	Missing Data due to faulty datalogger

Site Name	Start Date	Start Time	End Date	End Time	Code	Notes
Buckhorn	3/11/12	2:00	3/11/12	3:00	dst	daylight savings time
Dry Piney	1/31/12	11:00			rt-int	reset datalogger time- interpolated the one missing value in the hour
	3/11/12	2:00	3/11/12	3:00	dst	time change
Burma	3/11/12	2:00	3/11/12	3:00	dst	daylight savings time
	3/11/12	11:00	3/31/12	23:00	wc-wd	bad wiring connection; faulty wind direction
Speedway	1/1/12	0:00	1/4/12	12:00	wc-ws0	loose wiring connection, ws says 0 m/s
	3/6/12	12:00			aud	This hour contains DEQ Audit data, which was deleted from the record
	3/11/12	2:00	3/11/12	3:00	dst	daylight savings time
Two Rivers	3/11/12	2:00	3/11/12	3:00	dst	daylight savings time
Riverside	1/4/12	13:00			rt-int	reset datalogger time-interpolated one missing value
	3/1/12	14:00			rt-int	reset datalogger time-interpolated one missing value
	3/6/12	10:00			aud	this hour contains DEQ Audit data, which was deleted from the record
	3/11/12	2:00	3/11/12	3:00	dst	daylight savings time
Warren Bridge	1/4/12	15:00			rt-int	reset datalogger time-interpolated one missing value
	2/1/12	12:00			rt-int	reset datalogger time-interpolated one missing value
	3/11/12	2:00	3/11/12	3:00	dst	daylight savings time
Cottonwood Creek	2/14/12	17:00			End	Removed faulty datalogger
	2/14/12	18:00	3/9/12	15:00	md-dl	missing data b/c had to replace a faulty datalogger
	3/9/12	16:00			Start	Installed a new datalogger
	3/11/12	2:00	3/11/12	3:00	dst	daylight savings time
Trappers Point	1/31/12	8:00			rt-int	reset datalogger time- interpolated one missing value
	3/11/12	2:00	3/11/12	3:00	dst	daylight savings time
Mesa	1/5/12	10:00			rt-int	reset datalogger time- interpolated one missing value
	3/10/12	10:00	3/31/12	23:00	md	unknown error, datalogger did not record data

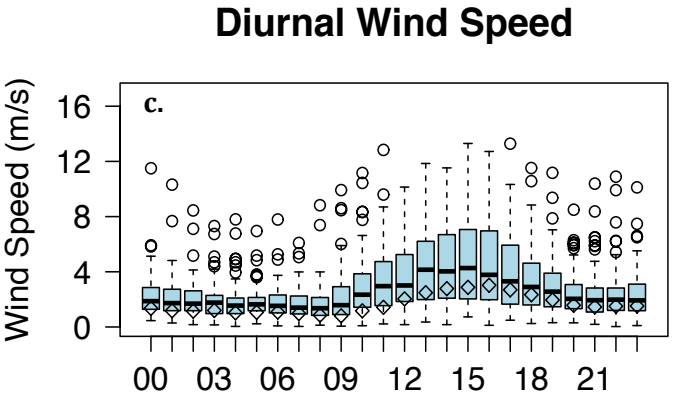
5.2.1 Buckhorn Data Summary

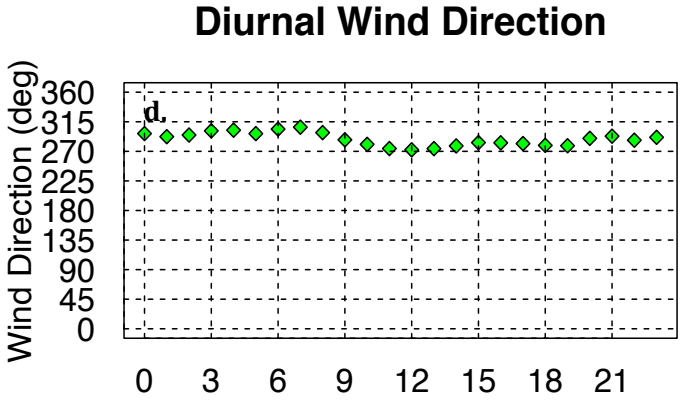
At Buckhorn, the wind speed ranged from calm (0.03m/s) to 13.30m/s. Looking at the wind rose for this site (Figure b.), overall, the wind was most frequently from the west and northwest quadrants. At wind speeds greater than 8 m/s the wind mostly blew from the west and southwest. Between 4 and 8 m/s, the wind was most frequently from two directions, southwest and northwest; at wind speeds between 2 and 4 m/s, the wind was most frequently from the WNW; and at wind speeds less than 2 m/s, the wind was most frequently from the NNW.

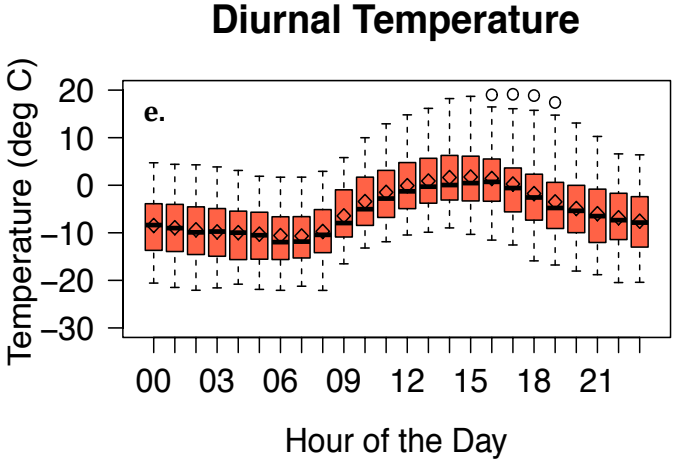
The diurnal profile of wind speed at Buckhorn shows that the highest wind speeds occur between early and mid-afternoon, and that the lowest wind speeds occur at night. The wind direction tends to vary between the northwest and west, with the morning wind shift occurring between 7:00 and 12:00, and the wind meandering back to its original direction by morning. The diurnal temperature profile shows minimum temperatures at 7:00, and maximum temperatures around mid-afternoon.

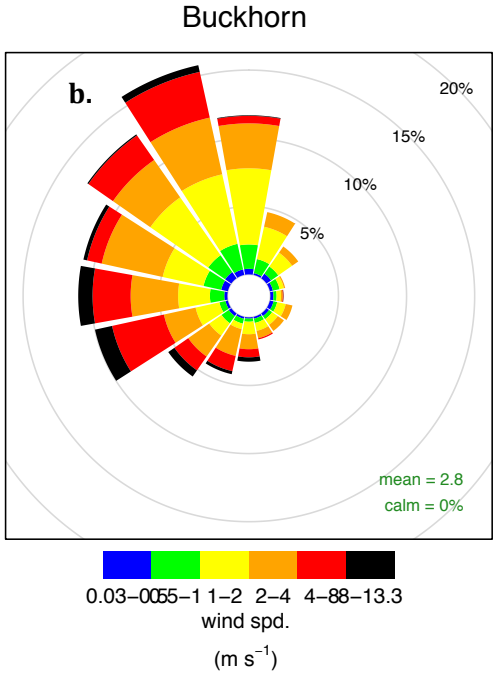
5.2.2 Buckhorn
(lat. 42.352, lon. -109.854, elev. 2162m)

a.	ws	wd	Temp
Min:	0.030	0.01	-22.110
1st Qu.:	1.260	198.70	-10.967
Median:	2.040	273.69	-5.440
Mean:	1.625	285.84	-5.151
3rd Qu.:	3.538	320.68	0.005
Max.:	13.300	359.90	19.120









Frequency of counts by wind direction (%)

f. Data Recovery Rates		
	Number	**Percent (%)**
a	2182	99.91
aud	0	0.00
md	0	0.00
md-dl	0	0.00
md-dst	2	0.09
rt-int	0	0.00
wc-wd	0	0.00
wc-ws0	0	0.00

Data Codes and Meanings	
a	Ambient
aud	Audit data
md	Missing Data
md-dl	Missing Data- faulty data logger
md-dst	Missing Data- daylight savings time
rt-int	Reset Time- interpolated missing values
wc-wd	Wiring Connection- faulty wind direction
wc-ws0	Wiring Connection- faulty wind speed of 0m/s

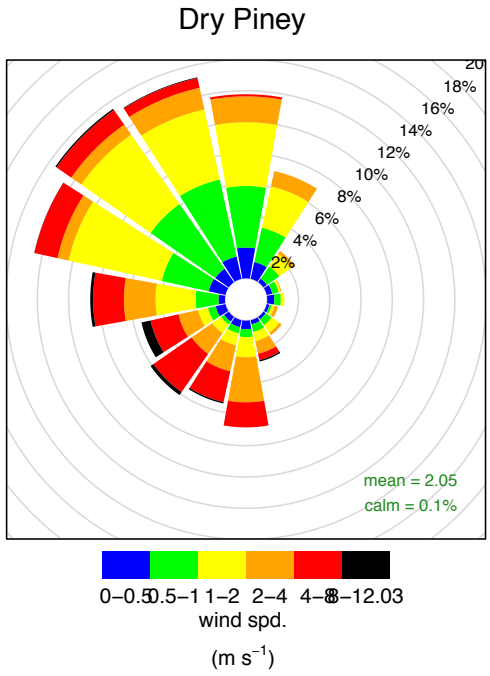
5.2.3 Dry Piney Data Summary

At Dry Piney, the wind speed ranged from calm (0.00 m/s) to 12.030 m/s; this site also had a greater frequency of calm winds than at Buckhorn. Overall, winds were most frequently from the northwest quadrant, but at wind speeds greater than 4m/s, the wind was most frequently out of the southwest quadrant. Additionally, at speeds between 2 and 4m/s, the wind typically blew from either the southwest or the northwest quadrant; however, the wind direction frequency maximum for this speed range was from the south. At wind speeds below 2m/s, the wind blew mostly out of the northwest quadrant.

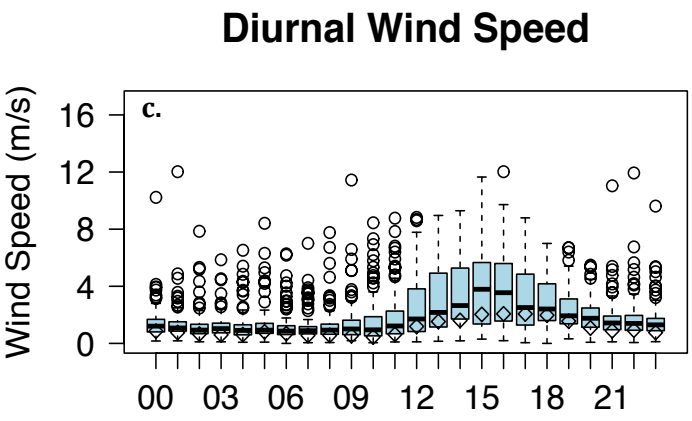
Diurnally, wind speeds were generally highest around 15:00, while the morning wind shift occurred between 9:00 and 11:00. This wind shift changes the wind direction from WNW to southwest, and then afterwards slowly meanders back to the original direction by the next morning. These changes in the wind coincide with the wind rose showing low wind speeds coming from the northwest quadrant and higher wind speeds from the southwest quadrant.

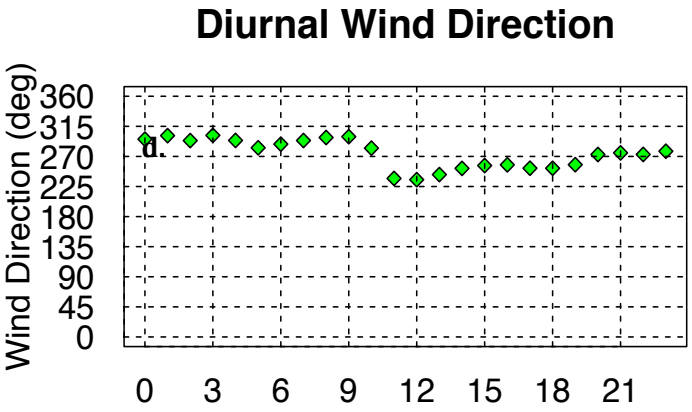
5.2.4 Dry Piney
(lat. 42.410, lon. -110.118, elev. 2058m)

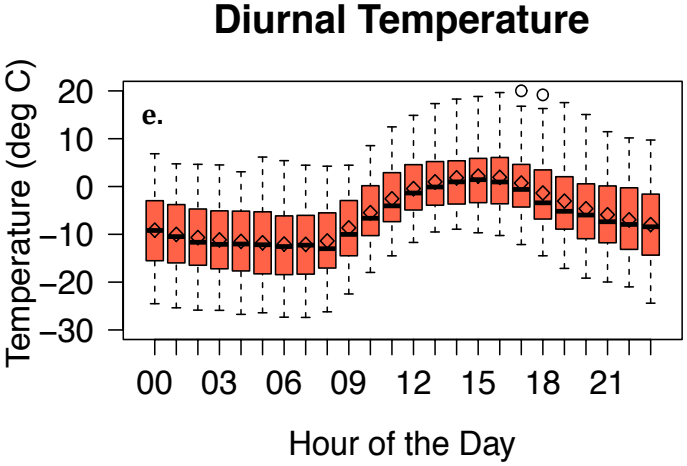
a.	ws	wd	Temp
Min:	0.000	0.01	-27.380
1st Qu.:	0.800	181.00	-12.588
Median:	1.300	270.32	-5.530
Mean:	0.996	266.22	-5.787
3rd Qu.:	2.580	317.47	0.468
Max.:	12.030	359.99	20.00



Frequency of counts by wind direction (%)







f. Data Recovery Rates		
	Number	**Percent (%)**
a	2181	99.86
aud	0	0.00
md	0	0.00
md-dl	0	0.00
md-dst	2	0.09
rt-int	1	0.05
wc-wd	0	0.00
wc-ws0	0	0.00

Data Codes and Meanings	
a	Ambient
aud	Audit data
md	Missing Data
md-dl	Missing Data- faulty data logger
md-dst	Missing Data- daylight savings time
rt-int	Reset Time- interpolated missing values
wc-wd	Wiring Connection- faulty wind direction
wc-ws0	Wiring Connection- faulty wind speed of 0m/s

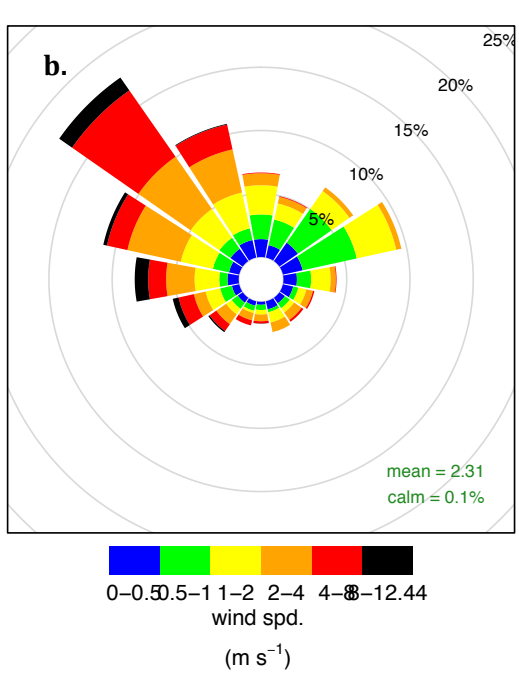
5.2.5 Burma Data Summary

The Burma site shows a slightly higher maximum wind speed than Dry Piney with wind speeds from 0.00 m/s to 12.44 m/s. Here, the wind most frequently blows from the northwest for wind speeds above 2 m/s; however, below 2 m/s there is a secondary directional frequency maximum from the ENE.

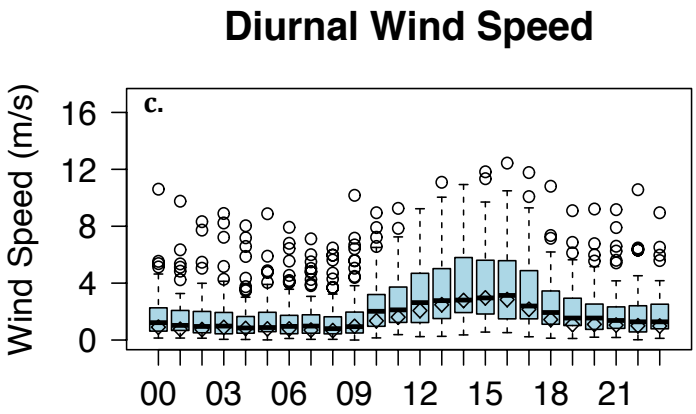
Wind speeds are typically the highest around mid-afternoon at this site. The morning wind shift occurs between 8:00 and 12:00, at which time the wind direction changes from NNW to WNW, and then gradually returns to the original direction throughout the remainder of the day. Temperatures follow the typical diurnal pattern of reaching a minimum just before the sun rises around 7:00, and reaching a maximum in the mid-afternoon around 15:00. This site only had a 77.43% data recovery rate for wind speed and direction due to the fact that there was a faulty wiring connection; this connection led to bad wind speed values for over half the month of March (see Table 3).

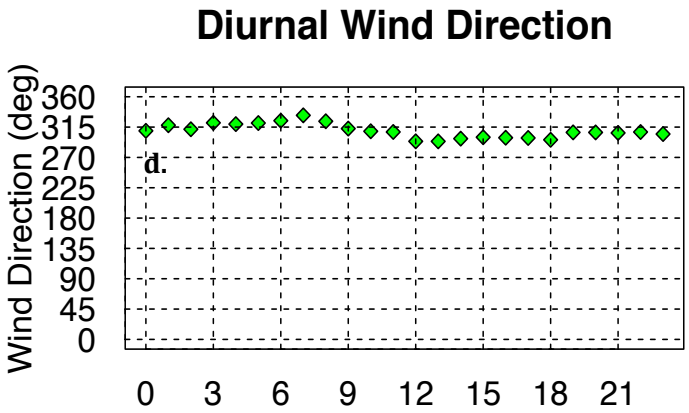
5.2.6 Burma
(lat. 42.448, lon. -109.772, elev. 2161m)

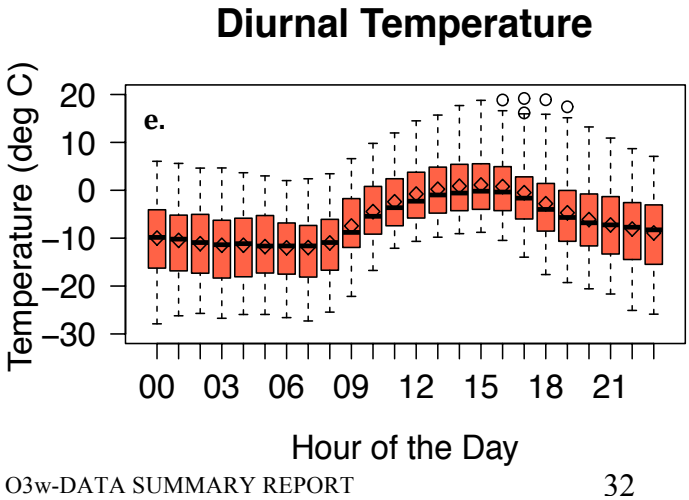
a.	ws	wd	Temp
Min:	0.000	0.06	-27.89
1st Qu.:	0.770	80.77	-12.00
Median:	1.490	263.49	-6.41
Mean:	1.35	305.04	-6.31
3rd Qu.:	3.120	313.36	-0.58
Max.:	12.440	359.87	19.19



Frequency of counts by wind direction (%)







f. Data Recovery Rates		
	Number	**Percent (%)**
a	1691	77.43
aud	0	0.00
md	0	0.00
md-dl	0	0.00
md-dst	2	0.09
rt-int	0	0.00
wc-wd	491	22.48
wc-ws0	0	0

Data Codes and Meanings	
a	Ambient
aud	Audit data
md	Missing Data
md-dl	Missing Data- faulty data logger
md-dst	Missing Data- daylight savings time
rt-int	Reset Time- interpolated missing values
wc-wd	Wiring Connection- faulty wind direction
wc-ws0	Wiring Connection- faulty wind speed of 0m/s

5.2.7 Speedway Data Summary

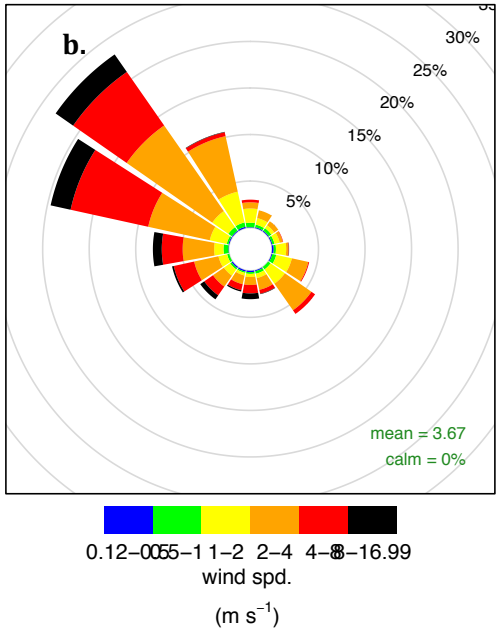
Speedway was one of the windier sites during this project. Wind speeds were a minimum of 0.12 m/s and reached a maximum of 16.99 m/s. For wind speeds above 4 m/s, the wind was most frequently from the northwest and the WNW, but for wind speeds between 2-4m/s there were two wind direction frequency maxima, one from the northwest quadrant and one from the southeast, although the northwest quadrant had a greater frequency of occurrences overall than the southeast. These directional frequency maxima also occurred for wind speeds less than 2m/s.

Diurnally at this site, the wind came from the WNW continuously throughout the day, although examining Figure d., a slight morning wind shift is visible between 9:00 and 11:00. This site had a slightly lower data capture rate than the majority of the other sites. At 95.97%, this site had a period of approximately four days where, due to a faulty wiring connection, the instrumentation recorded 0 m/s for all wind speed values (see Table 3).

5.2.8 Speedway
(lat. 42.553, lon. -109.611, elev. 2247m)

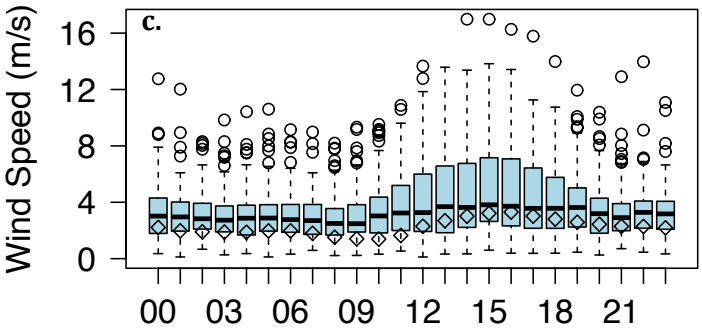
a.	ws	wd	Temp
Min:	0.120	0.16	-20.46
1st Qu.:	1.970	204.81	-10.31
Median:	3.110	290.84	-6.03
Mean:	2.218	289.68	-5.16
3rd Qu.:	4.543	312.25	-0.71
Max.:	16.990	359.57	18.07

Speedway

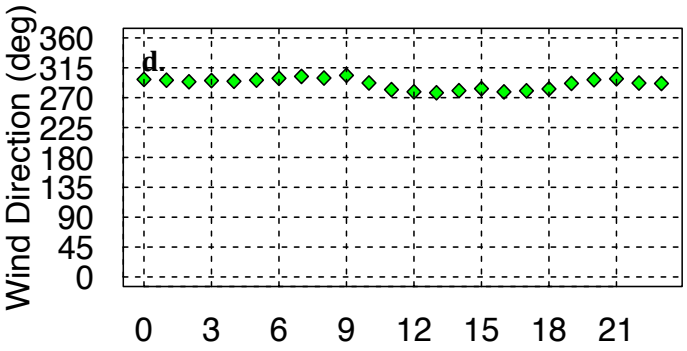


Frequency of counts by wind direction (%)

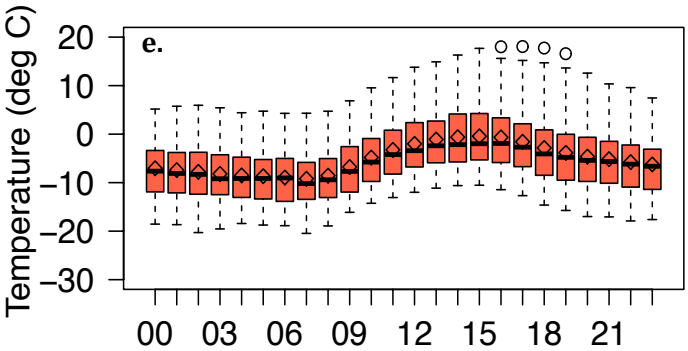
Diurnal Wind Speed



Diurnal Wind Direction



Diurnal Temperature



f. Data Recovery Rates		
	Number	**Percent (%)**
a	2096	95.97
aud	1	0.05
md	0	0.00
md-dl	0	0.00
md-dst	2	0.09
rt-int	0	0.00
wc-wd	0	0.00
wc-ws0	81	3.89

Data Codes and Meanings	
a	Ambient
aud	Audit data
md	Missing Data
md-dl	Missing Data- faulty data logger
md-dst	Missing Data- daylight savings time
rt-int	Reset Time- interpolated missing values
wc-wd	Wiring Connection- faulty wind direction
wc-ws0	Wiring Connection- faulty wind speed of 0m/s

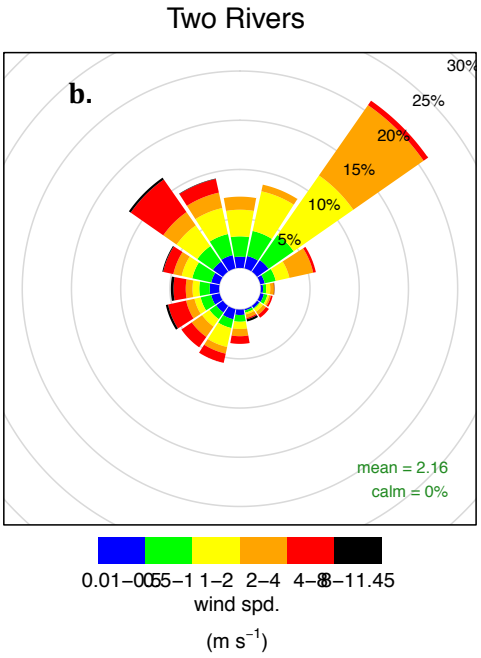
5.2.9 Two Rivers Data Summary

Two Rivers was one of the more calm sites in the network with maximum recorded wind speeds of only 11.45 m/s. This site had a very low frequency of wind speeds above 8 m/s, which is what could be expected from a site that is fairly sheltered inside a river valley. The wind most typically blew from the northeast, which was to be expected, as that is the along-valley direction for the New Fork River Valley; however, wind very seldomly blew from the southwest, which is the other along-valley direction that the wind could blow. This could be due to the intersection of the Green River Valley with the New Fork River Valley just to the southwest of the site location. A secondary wind direction frequency maximum is from the northwest, which is the direction of the Green River Valley from the site location. The wind direction with the lowest frequency of occurrences was the southeast quadrant, which is the direction of Ross Butte from the site location.

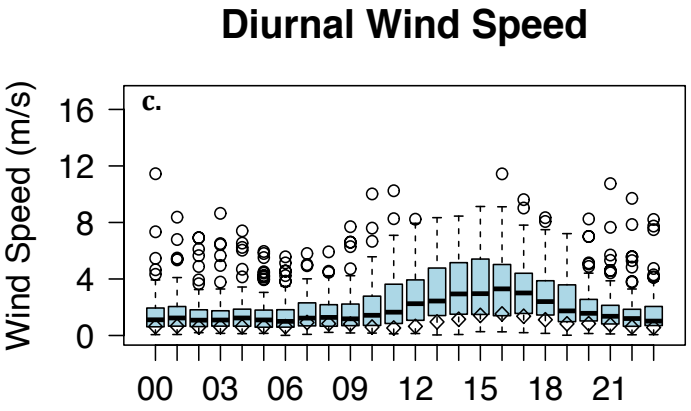
Diurnally, wind speeds were generally very low throughout the night, with a maximum in the mid-afternoon. The morning wind shift occurs between 9:00 and 13:00 and changes the wind direction from NNW to WNW. There is a secondary wind shift that occurs between 16:00 and 21:00, which changes the wind direction from WNW back to NNW.

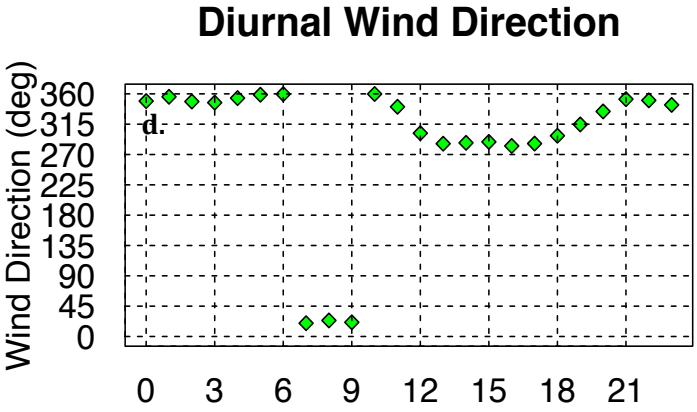
5.2.10 Two Rivers
(lat. 42.577, lon. -109.929, elev. 2092m)

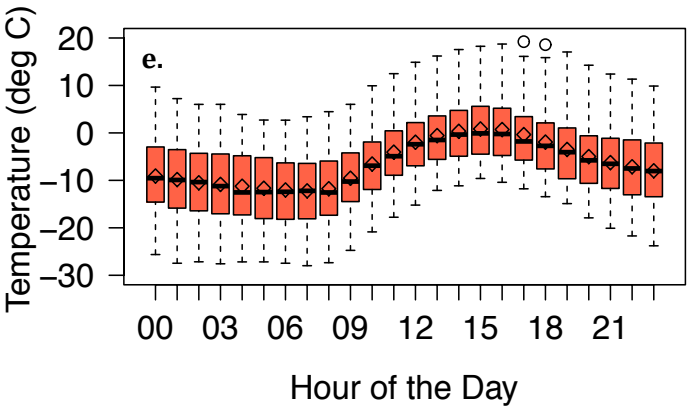
a.	ws	wd	Temp
Min:	0.010	0.17	-27.98
1st Qu.:	0.793	47.65	-12.46
Median:	1.530	201.42	-6.32
Mean:	0.678	327.32	-6.33
3rd Qu.:	2.978	303.32	-0.38
Max.:	11.450	359.89	19.22



Frequency of counts by wind direction (%)







f. Data Recovery Rates		
	Number	**Percent (%)**
a	2182	99.91
aud	0	0.00
md	0	0.00
md-dl	0	0.00
md-dst	2	0.09
rt-int	0	0.00
wc-wd	0	0.00
wc-ws0	0	0.00

Data Codes and Meanings	
a	Ambient
aud	Audit data
md	Missing Data
md-dl	Missing Data- faulty data logger
md-dst	Missing Data- daylight savings time
rt-int	Reset Time- interpolated missing values
wc-wd	Wiring Connection- faulty wind direction
wc-ws0	Wiring Connection- faulty wind speed of 0m/s

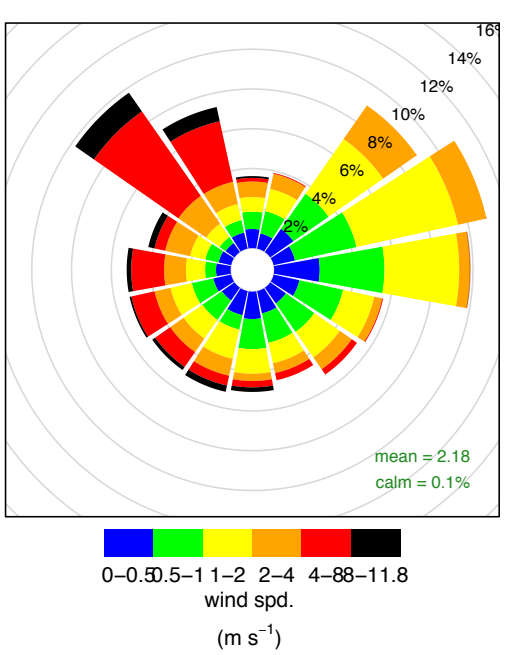
5.2.11 Riverside Data Summary

At this site, wind speeds ranged from calm (0.00 m/s) to 11.80 m/s. Looking at the wind rose, Riverside demonstrates the most stark wind speed and wind direction patterns of any of the sites shown thus far. At wind speeds above 4 m/s, the wind direction frequency maximum is from the northwest and NNW, but can also come from the SW and SE quadrants. At wind speeds, below 4 m/s, however, the wind can come from all directions, but most frequently comes from the ENE quadrant. The NW quadrant is the least common direction for low wind speeds.

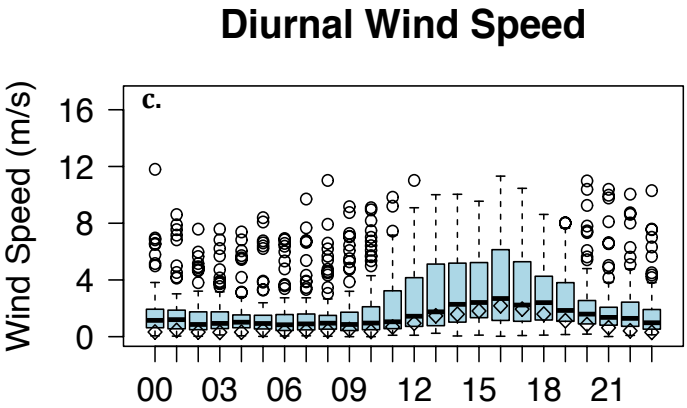
The morning wind shift at this site occurs between 8:00 and 12:00, changing the wind direction from the NNE to WNW. By around 21:00, the wind has turned so that it is blowing from the NNW, and from there it will return to the NNE by the next morning.

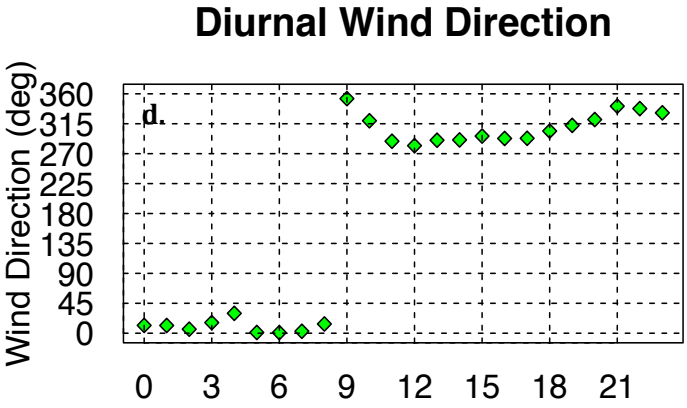
5.2.12 Riverside
(lat. 42.653, lon. -109.801, elev. 2127m)

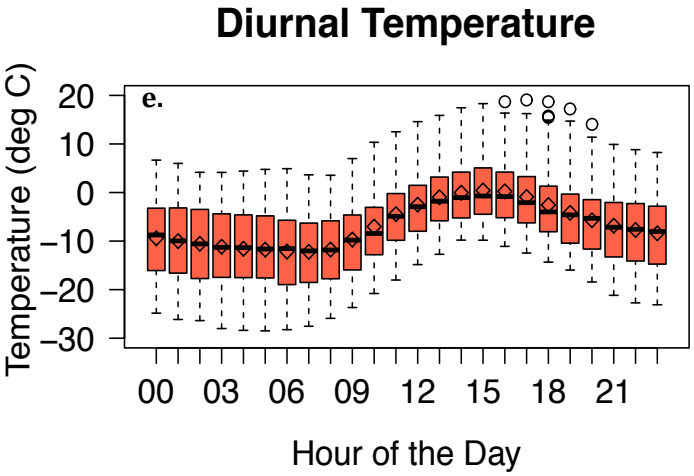
a.	ws	wd	Temp
Min:	0.000	0.61	-28.48
1st Qu.:	0.670	77.12	-12.74
Median:	1.250	163.07	-6.52
Mean:	0.719	312.10	-6.70
3rd Qu.:	2.690	272.08	-1.03
Max.:	11.800	359.92	19.07



Frequency of counts by wind direction (%)







f. Data Recovery Rates		
	Number	**Percent (%)**
a	2179	99.77
aud	1	0.05
md	0	0.00
md-dl	0	0.00
md-dst	2	0.09
rt-int	2	0.09
wc-wd	0	0.00
wc-ws0	0	0.00

Data Codes and Meanings	
a	Ambient
aud	Audit data
md	Missing Data
md-dl	Missing Data- faulty data logger
md-dst	Missing Data- daylight savings time
rt-int	Reset Time- interpolated missing values
wc-wd	Wiring Connection- faulty wind direction
wc-ws0	Wiring Connection- faulty wind speed of 0m/s

5.2.13 Warren Bridge Data Summary

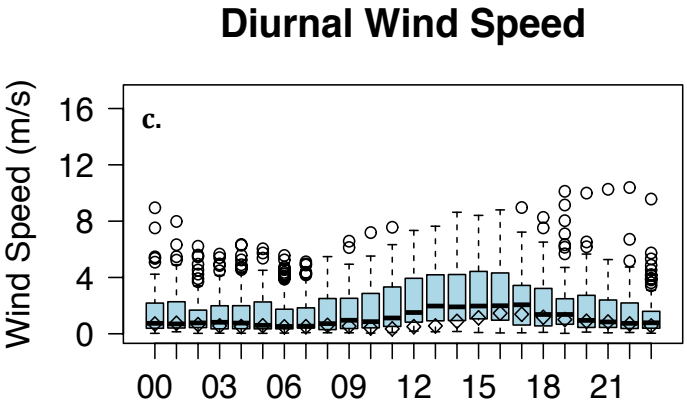
Warren Bridge was the calmest of any of the sites in the O3w mesonetwork, with a maximum wind speed of only 10.38 m/s and a relatively high frequency of wind speeds below 0.5 m/s. At wind speeds above 2 m/s, the two most frequent wind direction occurrences were from the northwest and southeast quadrants, but for wind speeds less than 2 m/s, the winds were most frequently from the northeast and northwest. The northeasterly wind direction at low wind speeds is consistent with the fact that the Green River flows from northeast to southwest less than 100 meters from the site location.

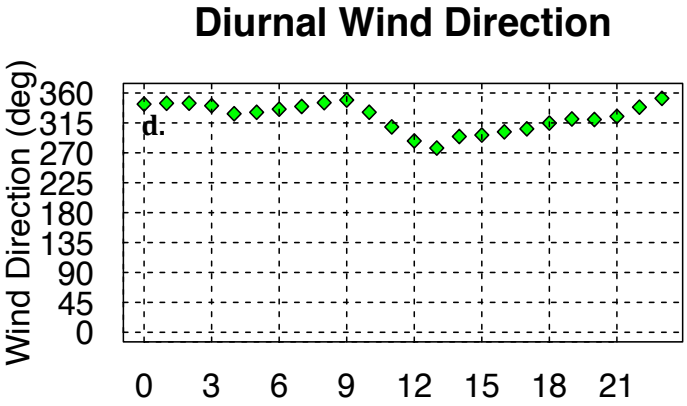
At this site, the morning wind shift occurs between 9:00 and 12:00, changing the wind direction from NNW to WNW, then slowly meandering back to the original direction by morning.

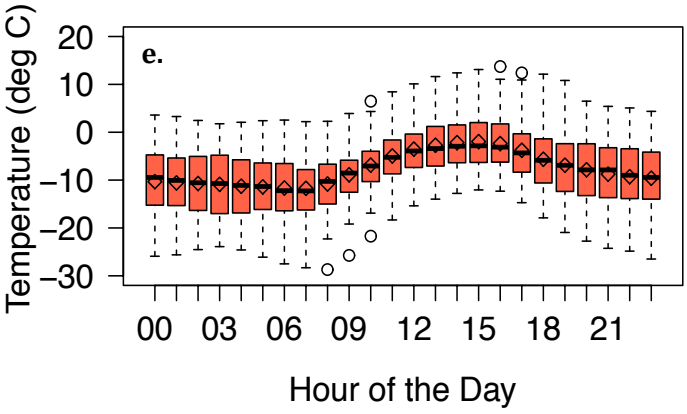
5.2.14 Warren Bridge

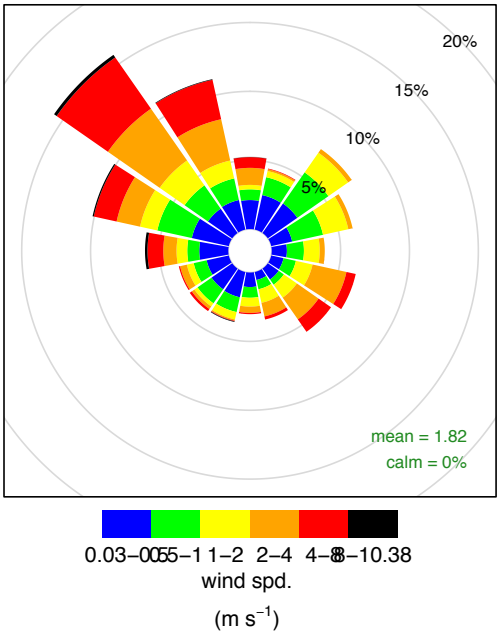
(lat. 43.018, lon. -110.119, elev. 2282m)

a.	ws	wd	Temp
Min:	0.030	0.09	-28.68
1st Qu.:	0.460	104.03	-12.59
Median:	1.010	233.47	-7.01
Mean:	0.695	321.05	-7.69
3rd Qu.:	2.788	310.51	-2.66
Max.:	10.380	359.64	13.74









Frequency of counts by wind direction (%)

f. Data Recovery Rates		
	Number	**Percent (%)**
a	2180	99.82
aud	0	0.00
md	0	0.00
md-dl	0	0.00
md-dst	2	0.09
rt-int	2	0.09
wc-wd	0	0.00
wc-ws0	0	0.00

Data Codes and Meanings	
a	Ambient
aud	Audit data
md	Missing Data
md-dl	Missing Data- faulty data logger
md-dst	Missing Data- daylight savings time
rt-int	Reset Time- interpolated missing values
wc-wd	Wiring Connection- faulty wind direction
wc-ws0	Wiring Connection- faulty wind speed of 0m/s

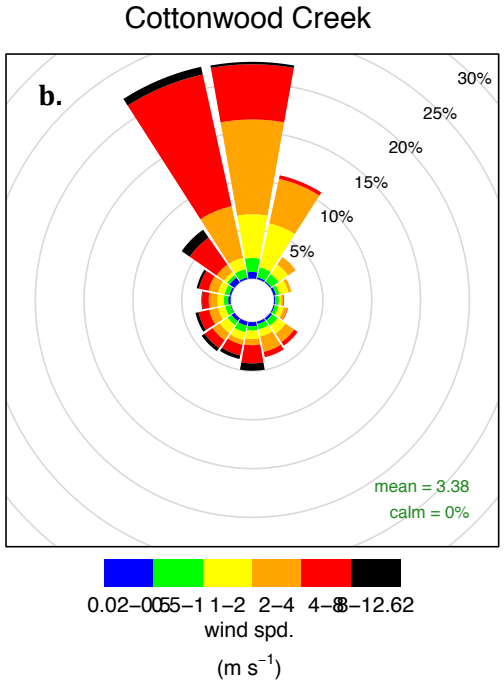
5.2.15 Cottonwood Creek Data Summary

Wind speeds at Cottonwood Creek ranged from 0.02 m/s to 12.62 m/s. The overall directional frequency maximum was very obviously from the north and NNW. For wind speeds above 8 m/s the winds most frequently came from the northwest and southwest quadrants. The wind direction frequency maximum for wind speeds between 4 m/s and 8 m/s is from the NNW by a very large percentage. For wind speeds less than 4 m/s, the wind is most frequently from the NNW to NNE.

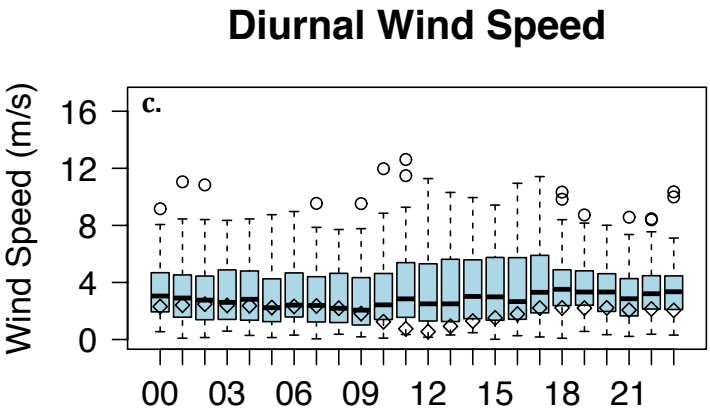
Diurnally, this site is much different from the other sites. One example is that diurnally, this site's wind speed does not change much throughout the day. Additionally, the morning wind shift occurs a couple of hours later than the other sites. This wind shift occurs between 10:00 and 13:00 where the wind changes from NNW to westerly, then meanders back to the original direction by morning. This site had a data recovery rate of 73.63% because of a faulty datalogger, which needed to be replaced, resulting in approximately 4 weeks' worth of missing data between February 14th and the beginning of March.

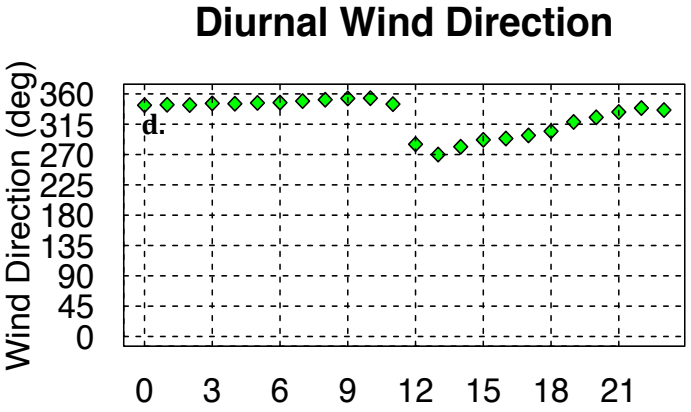
5.2.16 Cottonwood Creek
(lat. 42.719, lon. -110.079, elev. 2202m)

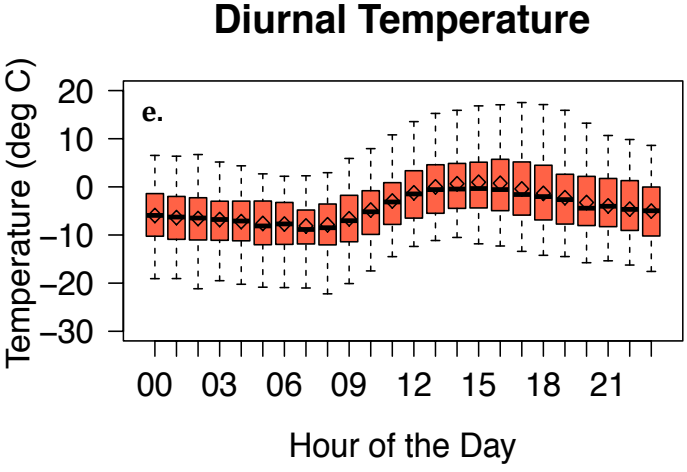
a.	ws	wd	Temp
Min:	0.020	0.02	-22.22
1st Qu.:	1.520	62.51	-9.28
Median:	2.870	242.90	-4.60
Mean:	1.774	331.32	-4.09
3rd Qu.:	4.860	337.70	0.70
Max.:	12.620	359.83	17.51



Frequency of counts by wind direction (%)







f. Data Recovery Rates		
	Number	**Percent (%)**
a	1608	73.63
aud	0	0.00
md	0	0.00
md-dl	574	26.28
md-dst	2	0.09
rt-int	0	0.00
wc-wd	0	0.00
wc-ws0	0	0.00

Data Codes and Meanings	
a	Ambient
aud	Audit data
md	Missing Data
md-dl	Missing Data- faulty data logger
md-dst	Missing Data- daylight savings time
rt-int	Reset Time- interpolated missing values
wc-wd	Wiring Connection- faulty wind direction
wc-ws0	Wiring Connection- faulty wind speed of 0m/s

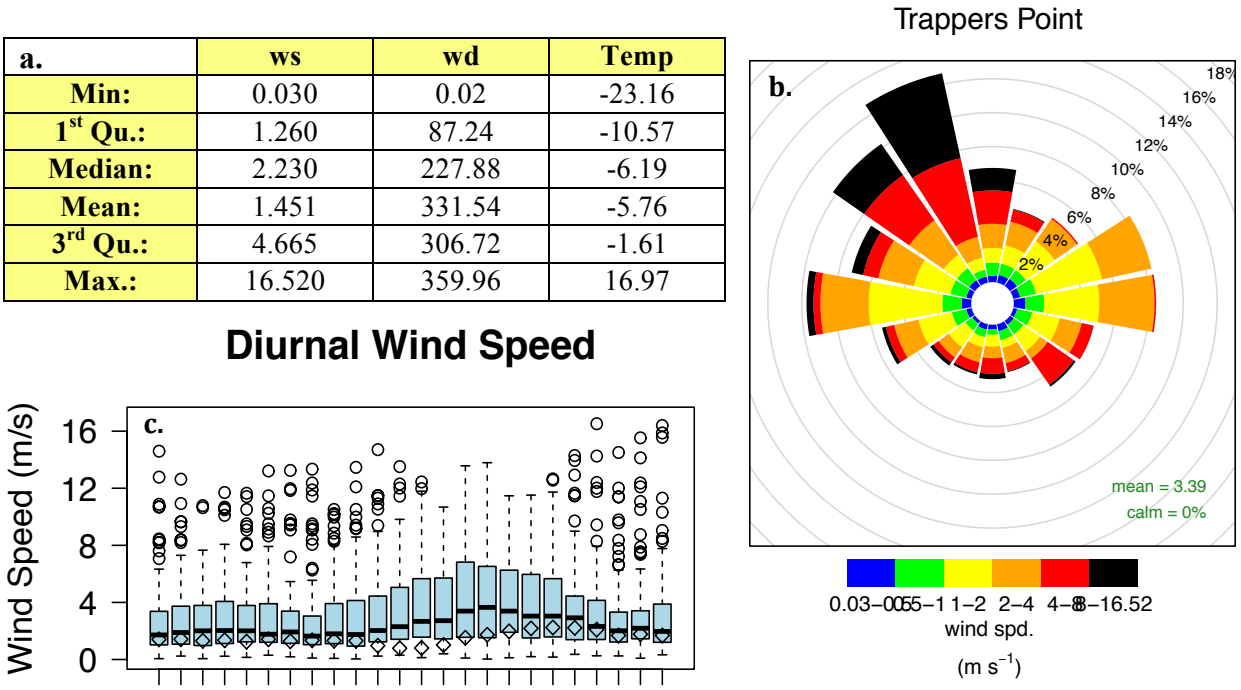
5.2.17 Trappers Point Data Summary

Another windy site in the network, Trappers Point had a wind speed range of 0.03 m/s to 16.52 m/s, with a high frequency of wind speeds above 8 m/s. At wind speeds above 8 m/s the wind was most frequently from the northwest quadrant. For wind speeds between 4 and 8 m/s, the wind was most frequently from the northwest and southeast quadrants, although the frequency of occurrences is much higher for the northwest quadrant. In contrast, for wind speeds less than 4 m/s, the wind either comes from the east or west.

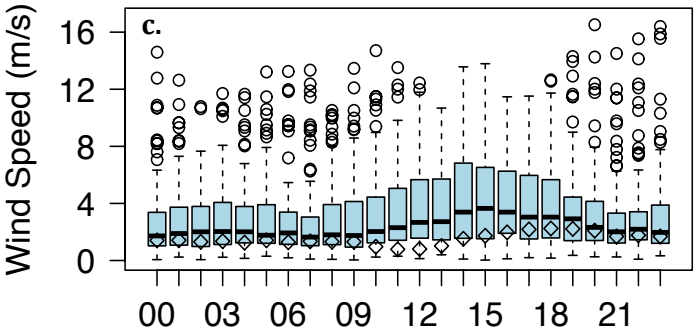
At this site, the morning wind shift is slight, changing the wind direction from NNW to west between 8:00 and 12:00, then meanders back to its original direction by the next morning.

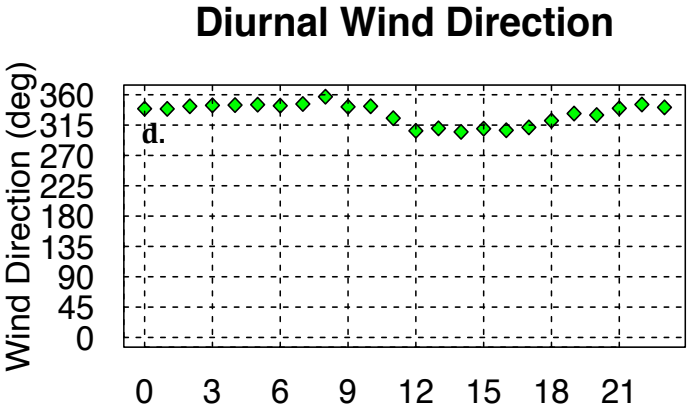
5.2.18 Trappers Point
(lat. 42.880, lon. -109.981, elev. 2242)

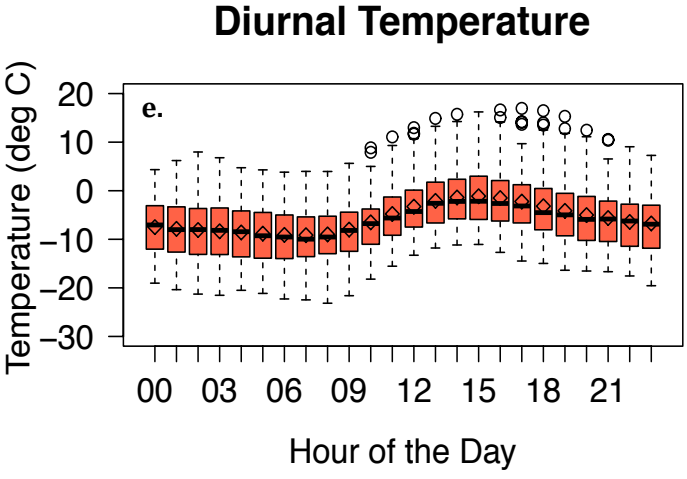
a.	ws	wd	Temp
Min:	0.030	0.02	-23.16
1st Qu.:	1.260	87.24	-10.57
Median:	2.230	227.88	-6.19
Mean:	1.451	331.54	-5.76
3rd Qu.:	4.665	306.72	-1.61
Max.:	16.520	359.96	16.97



Frequency of counts by wind direction (%)







f. Data Recovery Rates		
	Number	**Percent (%)**
a	2181	99.86
aud	0	0.00
md	0	0.00
md-dl	0	0.00
md-dst	2	0.09
rt-int	1	0.05
wc-wd	0	0.00
wc-ws0	0	0.00

Data Codes and Meanings	
a	Ambient
aud	Audit data
md	Missing Data
md-dl	Missing Data- faulty data logger
md-dst	Missing Data- daylight savings time
rt-int	Reset Time- interpolated missing values
wc-wd	Wiring Connection- faulty wind direction
wc-ws0	Wiring Connection- faulty wind speed of 0m/s

5.2.19 Mesa Data Summary

The Mesa had a range of wind speeds that was seen at many other sites, ranging from 0.08 m/s to 12.41 m/s, but wind speeds were most frequently greater than 2 m/s. At this site, the wind direction frequency maximum for all wind speeds was from the northwest quadrant. There is a very small percentage of the time when the wind came from the southeast, but this small percentage could still be considered a second wind direction frequency maximum.

Diurnally, like the Cottonwood Creek site, there is not much variation in the mean wind speed throughout the day; however, this site is different, since there is no morning wind shift to be observed. This site had a 76.24% data recovery rate because of an unknown error that caused the data logger to not record data from March 11th until the beginning of April.

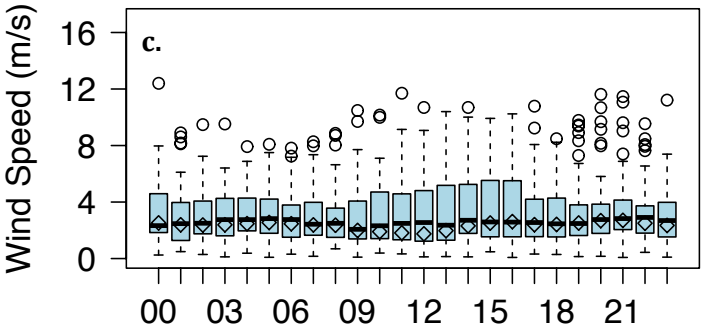
5.2.20

Mesa

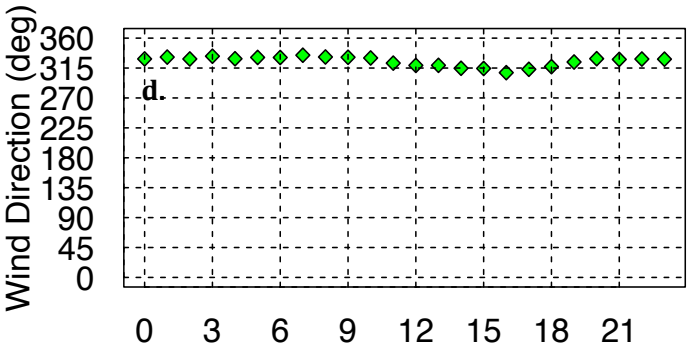
(lat. 42.752, lon. -109.858, elev. 2284)

a.	ws	wd	Temp
Min:	0.080	0.0	-20.11
1st Qu.:	1.550	166.3	-10.87
Median:	2.595	311.6	-7.35
Mean:	2.329	2.329	-7.36
3rd Qu.:	4.250	332.5	-4.26
Max.:	12.410	360.0	7.69

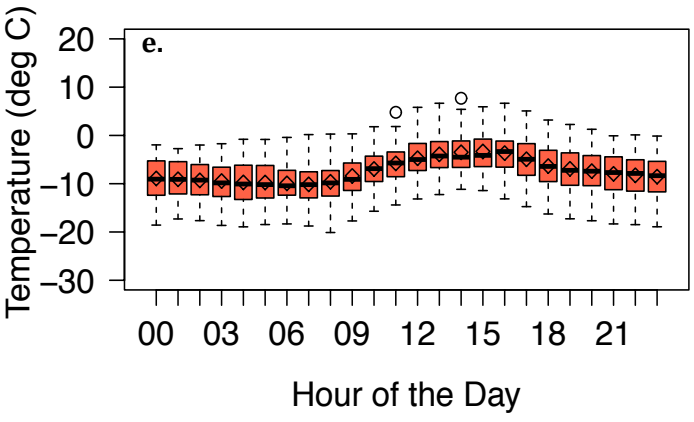
Diurnal Wind Speed



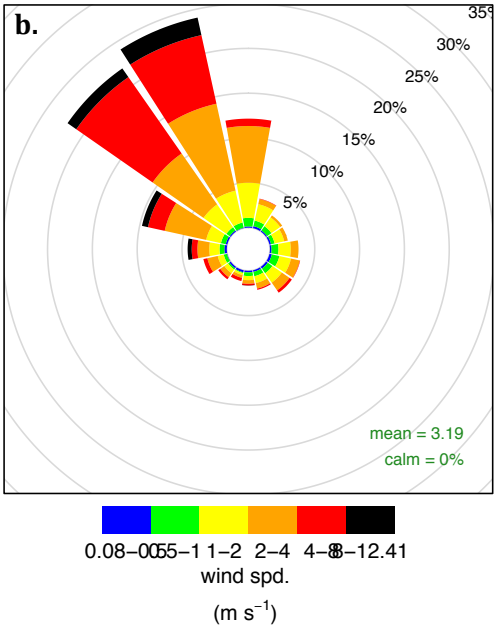
Diurnal Wind Direction



Diurnal Temperature



Mesa



Frequency of counts by wind direction (%)

f. Data Recovery Rates		
	Number	**Percent (%)**
a	1665	76.24
aud	0	0.00
md	518	23.72
md-dl	0	0.00
md-dst	0	0.00
rt-int	1	0.05
wc-wd	0	0.00
wc-ws0	0	0.00

Data Codes and Meanings	
a	Ambient
aud	Audit data
md	Missing Data
md-dl	Missing Data- faulty data logger
md-dst	Missing Data- daylight savings time
rt-int	Reset Time- interpolated missing values
wc-wd	Wiring Connection- faulty wind direction
wc-ws0	Wiring Connection- faulty wind speed of 0m/s

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A1: O3W STANDARD OPERATING PROCEDURES

University of Wyoming
Upper Green River Basin Ozone Wind Field Investigation (O3w)

Pre-Deployment Equipment Check and Set-up
Standard Operating Procedure 01

May 2012

Title	Name	Signature
Principle Investigator	Brittni Emery	
Project Manager	Dr. Robert Field	

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1.0 PURPOSE AND APPLICABILITY

This SOP details all of the procedures to be followed prior to the deployment of the mesonets for field work. There are two sets of mesonet instruments for which there are instructions, one set uses slightly older technology, which includes CR206 dataloggers, RM Young model 05305-AQ wind monitors, and 109-L temperature probes, while the other set uses CR850 dataloggers, RM Young model 05103 wind monitors, and 107-L temperature probes.

Section 2.0 details the steps to make sure that the CR206 dataloggers and the RF401 radio are communicating properly. Section 3.0 describes how to program the CR206 and CR850 dataloggers. Section 4.0 details the set up and calibration procedures for the RM Young model 05305 Wind Monitor-AQ. And Section 5.0 shows how to set up and calibrate the RM Young model 107-L and 109-L Temperature probes.

PC400 is the main program that will be used to program dataloggers and collect data.

The main screen for PC400 provides three tabs for communications functions (Clock/Program, Monitor Data, and Collect Data), as well as buttons to launch utilities for working with data files (View, Split, and Card Convert) and for generating or editing datalogger programs (Short Cut, CRBasic, and EDlog). There is also a button to launch the Device Configuration Utility (or DevConfig). Two additional stand-alone utilities are installed with PC400 and can be opened from the Windows Start menu, Programs | Campbell Scientific | PC400 | Utilities. These utilities are Transformer and File Format Convert. Some of these functions will be described later in SOPs 01, 03 and 04.

The Device Configuration Utility (DevConfig) is used to set up dataloggers and associated devices before those devices are deployed in the field and before the devices are added to networks in the PC400 software.

DevConfig can not only send operating systems to supported device types, but can also set datalogger clocks and send program files to dataloggers. It also provides a reporting facility where a summary of the current configuration of a device can be shown on the screen and printed. This configuration can be saved to a file and used to restore the settings in the same or a replacement device.

The Short Cut program generator creates programs for Campbell Scientific dataloggers in four steps. The user will select the datalogger, choose how often and which sensors will be measured, and select intervals or trigger conditions on which to store data, and what processing to perform on the raw measurements for final storage. Short Cut also generates a wiring diagram for connecting the sensors to the datalogger.

The “Collect Data” tab shows a list of the final storage areas or tables in the datalogger. You can either retrieve the uncollected data, appending it to a file on the PC, or you can retrieve all of the data from the datalogger, overwriting the file on the PC if it already exists.

1.1 RF401-to-CR206 Communication

Ensuring telecommunications between the RF401 spread-spectrum radio and the CR206X datalogger prior to deployment is a key aspect of ensuring quality data for O3w. This is important because radio communication is the primary method we are using to collect the data from the CR206X dataloggers; however, the factory settings of these devices do not match. Consequently, they must be reconfigured using DevConfig before communication can take place. Instructions can be found in Section 2.0.

Because a radio connection will not be used to transmit data from the CR850 dataloggers, the device need not be configured using DevConfig.

1.2 CR206 and CR850 Programming

Programming the datalogger allows you to specify which variables you wish to collect, how often they will be collected, and how often those values are averaged and stored. Detailed instructions can be found in Section 3.0.

A user working with these instructions, as well as the PC400 User's Manual from which much of this SOP was taken, should be able to program the CR206 and CR850 Dataloggers to fit their needs.

1.3 RM Young Model 05103 and Model 05305-AQ Wind Monitors

The purpose of calibration and maintenance is to assure quality data capture and minimize data loss by performing and documenting scheduled operational checks and preventative maintenance. The technical instructions in Section 4.0 provide specific details to dynamically calibrate both an R.M. Young model 05103 and a model 05305-AQ wind monitor.

Persons using these instructions and the manufacturer's instrument and calibration manuals should be able to adjust the equipment to fully meet all defined specifications.

Calibrations are required under any of the following circumstances:

- Upon acceptance testing of a new instrument
- Upon installation or removal of the instrument at a field station
- Whenever control limits are exceeded
- Prior to any corrective action, service, or maintenance to any portion of the instrument that affects its operational principle

It is important to note that, while the sensor mechanically rotates through 360°, the full-scale wind direction signal from the instrument occurs at 355°, leaving an open circuit between 355° and 0°.

1.4 RM Young Model 109-L and Model 107-L Temperature Probes

The purpose of calibration and maintenance is to assure quality data capture and minimize data loss by performing and documenting scheduled operational checks and preventive maintenance. Section 5.0 provides specific details for calibration of an R.M. Young model 109 Temperature Probe.

1.5 Definitions

- Dynamic Check: A dynamic check implies subjecting a sensor to known conditions similar to those conditions under normal sampling. A dynamic check of a wind direction sensor would be to point the vane to a known landmark and comparing the sensor output with the measured landmark azimuth.

- Signal Conditioning Card: An electronic circuit card that provides operational voltages to the meteorological sensor and converts the raw sensor signal to a linear analog output suitable for recording; otherwise known as the datalogger.

2.0 RF401-TO-CR206 RADIO COMMUNICATIONS

2.1 Summary of the Method

You must change the default settings of the CR206(X) and RF401. These devices will not communicate with each other using the default settings. A person using this SOP, along with the Campbell Scientific *Quick Reference Guide for Setting Up RF401-to-CR206 Communications*, from which much of this section was taken, should be able to set up communications between the two devices.

2.2 Equipment and Supplies

- 12VDC power supply to power the CR206(X) datalogger
- Standard 9-pin serial cable
- RS-232 to serial adapter, if needed
- Campbell Scientific PC400 Software installed on a laptop
- #15966 wall charger to power the RF401 radio

2.3 Procedural Steps

2.3.1 Install PC400 Software

- Insert the CD and follow the prompts to complete installation. You will find the CD key printed on the back of the jewel case for the original installation CD.
- A shortcut will appear under the computer's Start menu under Programs | Campbell Scientific | PC400.

2.3.2 CR206 Setup Information

- Apply 12 VDC power to the battery terminals on the CR206(X).
- Connect the CR206(X) to a COM port on your computer using a standard 9-pin serial cable. An RS-232 to serial adapter may be needed.
- Open and run the device configuration program in the PC400 software (DevConfig).
- Under Device Type, click "CR200 Series".
- Select the Serial Port matching the COM port on your computer.
- Click the "Connect" button to establish communications with the datalogger. The Deployment panel in DevConfig will be displayed and the DevConfig parameters can now be entered.
- Enter the datalogger "PakBus Address" that matches the PC400 communications software setting for the CR206(X)'s PakBus Address.

  You can only access the data logger by using the correct site program with the corresponding PAKBUS address, i.e., site 3 can only be accessed using the program/configuration configured for PAKBUS address 3. Below is a list of all site names/numbers (Note: The default Pakbus address will be used for CR850 sites, as noted by *)

  Table 1: Site Names and PakBus Addresses

Site Name	Pakbus Address
01_Buckhorn	*
02_Dry Piney	*
03_Burma	3
04_Speedway	4
05_Two Rivers	5
06_Riverside	*
07_Warren Bridge	*
08_Cottonwood Creek	8
09_Trappers Point	9
10_Mesa	*

- Choose "PakBus Aware" under "RF Protocol".
- Enter radio "Hop Sequence" 0. This number will be the same for all devices.
- Enter 0 for the radio "Network" address.
- Enter the radio "Power Mode" that works with the RF401's power mode. Choose either 1 sec with long heading.
- Click the "Apply" button to send the entered settings to CR206(X), and when prompted, save the settings to your computer.

2.3.3 RF401 Setup Information

- Connect power cable to the "CD Pwr" jack of the RF401
- Use a standard 9-pin serial cable to connect the RF401's RS-232 port to a COM port on your PC.
- Run DevConfig
- Click on "RF401" in DevConfig.
- Click on the "Connect" button in DevConfig.
- Press the "Program" button on the RF401, and DevConfig will display the Deployment panel – defaulting to the RF401/RF411/RF416 tab.
- Select the "Active Interface". This should be set to either the "AutoSense" or "RS-232" mode.
- Select "PakBus Aware" for the "Protocol" setting; the CR206(X)'s "RF Protocol" should be PakBus.
- Enter 9600 for the "RS-232 Baud Rate".
- Select "Hop Sequence" 0.
- Select "Net Address" 0. Should match the number on all devices.
- The "Radio Address" is fixed at 0 when the RF protocol is PakBus.
- Select the Pin enabled power mode. The power mode for the RF401 and the CR206 needs to match so they can get each other's attention.
- Select "Retry Level" Low.
- If using the "PakBus Node" protocol, select the PakBus tab and create a PakBus Address for the RF401.
- Click the "Apply" button to send the entered settings to the RF401.

3.0 CR206 AND CR850 PROGRAMMING

3.1 Equipment and Supplies

- CR206 or CR850 datalogger and associated power supply
- RS-232 cable
- RS-232 to serial adapter, if needed
- PC loaded with PC400 software

3.1.1 The CR206 Datalogger

- The CR206 contains a 915mHz spread spectrum radio.
- Data are copied, not moved, from the CR206 to the PC.
- A RS-232 port is integrated with the CR206 to facilitate data collection.
- A lithium battery backs up the CR206 clock, program, and memory if it loses power.
- The CR206 is powered by a nominal 12 volt DC source and solar panels will be used to charge the battery.
- An FCC authorized antenna is required.
- The CR206 communicates via PakBus, a proprietary network communications protocol.

- It is extremely important that the CR206 be protected from moisture. This can be accomplished by storing the CR206 in a cooler, but avoiding setting the datalogger on the bottom of the cooler by placing a towel under the datalogger or covering the device in a plastic bag.
- The CR206 uses an internal voltage reference to routinely calibrate itself. To maintain electrical specifications, Campbell Scientific recommends factory recalibration every two years.

3.1.2 The CR850 Datalogger

- A RS-232 port is integrated with the CR850 for data collection
- Data are copied, not moved, from the CR206 to the PC
- The CR850 contains a display and keypad for easy access to programs and data
- The CR850 is powered by a 12 volt DC source and solar panels will be used to charge the battery.
- Contains 4MB of battery-backed SRAM for CPU usage, program storage and data storage.

3.2 Procedural Steps

3.2.1 Make Connections

- Connect 12 DVC external power source to the CR206 by inserting the positive lead into the “Battery +”.
- Insert the negative lead into the “Battery -“.
- For the CR850, insert the green power plug to power the device. Make sure a battery is connected to the power distributor.
- Connect the RS-232 cable between the RS-232 port on the CR206 or CR850 and the RS-232 port on the PC.
- Note: The PC400 software supports direct connect via an RS-232 cable for both datalogger types, or via RF401 spread-spectrum radio for the CR206 dataloggers.

3.2.2 EZSetup Wizard

- Dataloggers are added to the network with the EZSetup Wizard. The wizard is also used to edit the settings for a datalogger after it’s been added. The EZSetup Wizard can be opened by clicking the “Add” or “Edit” buttons.
- During the “Communication Setup” step you select the datalogger type (CR206) and give it a name that will also become the default file name for data files collected from that datalogger. A list of the datalogger names appears in Table 1.
- In the “Datalogger Settings” section, enter a baud rate of 9600 for CR206. This number may be different for CR850 dataloggers.
- The “Communications Test” step allows you to test the communications link before going any further. If the datalogger is not installed, you can skip this and the next two steps.

- If communications succeeds, you can move to the "Datalogger Clock" step where you can check or set the datalogger's clock to match the PC's system time.
- The "Send Program" step allows you to send a program to the datalogger. We will be sending a program to the datalogger later from the "Clock/Program" tab. The program will be created from the instructions found in Section 3.3 of this SOP.

3.2.3 Clock/Program Tab

- Once you've added a datalogger, you may use other buttons on the "Clock/Program" tab to delete it, edit its settings, or add another datalogger.
- Note: PC400 will never hang up on the datalogger unless you click "Disconnect", move out of range of the radio signal, or unplug the RS-232 cord.

3.2.4 Monitor Data Tab

- Once you've added and connected to a datalogger, you can monitor the values stored in the datalogger using the "Monitor Data" tab. PC400 will display the last record from a final storage table and will automatically update these records as they are stored in the datalogger's memory.
- Note: PC400 does not automatically save this data to the data file. Any data that are to be saved must be collected manually from the "Collect Data" tab.

3.3 Short Cut Program Generator

- Note: Short Cut not only generates a program for the datalogger, but also a wiring diagram that can be left with the datalogger for field servicing.
- After generating a program, the user can send it to the datalogger from the "Results" tab of Short Cut's "Finish" screen or from "Connect Screen".
- After opening, Short Cut presents a wizard that walks you through the steps of creating a datalogger program.

3.3.1 Step 1: Create a New File or Open Existing File

- To begin creating a new program, press the "New Program" button and select the CR200 (CR800) Series from the dialog box. You will have to create a separate program for each datalogger type.
- Short Cut will then ask for a Scan Interval, or period for each measurement cycle. Choose 60 second.
- Next, an "AC Noise Rejection" dialog box will open. Choose 60 Hz.
- Next, choose the Campbell Scientific Inc. (US) option from the "Sensor Support" dialog box.

3.3.2 Step 2: Choose Sensors to Monitor

- In this step, the user chooses which sensors will be measuring.

- For systems with CR206 dataloggers, choose Meteorological | Wind Speed and Direction | RM Young model 05305 Wind Monitor-AQ, and Temperature | RM Young model 109 temperature probe.
- For systems with CR850 dataloggers, choose Meteorological | Wind Speed and Direction | RM Young model 05103 Wind Monitor, and Temperature | RM Young model 107 temperature probe.

- Note: most sensors will require you to at least review the default settings for that measurement, including the measurement name, units, etc. Temperature will be measured in Celsius and wind speed will be measured in meters per second.
- Note: A wiring diagram can be found by clicking on the "Wiring Diagram" text on the left hand side of the window. This diagram will be used to attach the sensors to the datalogger in SOP 02.

3.3.3 Step 3: Set Up Output Tables

- After selecting the sensors to be measured, the user can choose which data to store using the Outputs step.
- To store a measurement to final storage, simply click on a "Measurement" label on the left, choose the data processing you want for that measurement by clicking one of the enabled buttons in the middle, and Short Cut adds the necessary instructions to save that data. For O3w, data that will be stored are 1-minute averages (from 10 second samples), and 5-minute, 60 minute, and daily averages, as well as daily maximum, minimum, and standard deviation of wind speed and temperature.
- Change the "Table Name" to Site_3, if the datalogger will be at site 3.
- Change the "# Records" field to -1, which means auto-allocate.
- When all outputs are configured, click "Finish".

3.3.4 Step 4: Generate the Program in the Format Required by the Datalogger

- If you haven't saved the program yet, Short Cut asks for a program name and offers the default directory within its program working directory. The default working directory is C:/Campbellsci/SCWin.
- The file produced will be a .BIN (binary image) file.
- *ProgramName*.DEF is the text file that describes the wiring for the sensors and devices to the datalogger, measurement labels, flag usage, and the output expected. You can view the contents of the DEF file by clicking the Summary button on the results screen.
- Click the "Send Program" button to send the program to the datalogger.

4.0 RM YOUNG MODEL 05103 AND 05305-AQ WIND MONITORS

4.1 Equipment and Supplies

The following equipment and materials are generally required to calibrate and maintain wind speed and wind direction sensor systems:

- R.M. Young Model 18801 or 18802 anemometer drive motor
- Torque disk and weights
- Model 18112 vane angle bench stand
- R.M. Young instrument manual
- Field service tools
- Field notebook
- Wind Speed Calibration Forms
- Wind Direction Calibration Forms

4.2 Methods

The wind system must by dynamically checked (pre-maintenance calibration) before any electrical adjustments are made or before servicing the meteorological sensors. Throughout the calibration and maintenance period, the field notebook and calibrations forms must be annotated to indicate that data taken during the calibration period should not be included as standard observations.

After performing system adjustments and maintenance, the system again needs to be dynamically checked (post-maintenance calibration) to ensure proper orientation of the sensors. The pre-and post-maintenance calibration techniques are identical. Do not adjust the signal conditioning cards or perform any maintenance to the sensors until all pre-calibration checks are completed.

When performing calibration checks, complete the O3w Calibration sheets. Be sure to indicate on the form whether the calibration is pre-or post-maintenance and note all maintenance activities or replaced components in the "Comments" field.

Quality objectives for wind observations are presented in Table 1.

Table 2: Monitoring quality objectives for surface wind measurements.

Accuracy (instrument specifications)	
Horizontal Wind Speed	± 0.25m/s for ws ≤ 5m/s
	± 5% for ws > 5m/s
Horizontal Wind Direction	± 5 degrees
Propeller Torque	< 1gm-cm
Directional Torque	≤ 11 gm-cm for 05305-AQ
	≤ 20 gm-cm for 05103

4.3 Initial Check

When the wind monitor is unpacked it should be checked carefully for any signs of shipping damage. Remove the plastic nut on the propeller shaft. Install the propeller on the shaft with the serial number of the propeller facing forward (into the wind). The instrument should be checked mechanically and electrically before installation. The vane and propeller should easily rotate 360 deg. without friction. Check vane base by holding the instrument base so the vane surface is

horizontal. It should have near neutral torque without any particular tendency to rotate. A slight imbalance will not degrade performance.

4.4 Calibration Checks

Calibration checks will be performed before deployment, as well as at the beginning and ending of the field project. Should any operational check be out of suggested tolerance, complete the calibration check before any maintenance or adjustments are made. The following operational checks should be performed:

CONNECT INSTRUMENTS:

Connect the wind monitor to a datalogger and connect the datalogger to the field computer. For connecting a model 05305-AQ wind monitor to its datalogger, connect the wires to the datalogger using the diagram provided in Figures 1 and 2 of the SOP Appendix. For model 05103 dataloggers, simply plug the cables into the plugin on the bottom of the housing box. Then start the PC400 software, and connect to the appropriate datalogger. Click on the 'Monitor Data' tab so that the 'Public' data are being displayed. This data will be updated every 10 seconds.

ANNOTATE DATA RECORDS:

Make an entry in the field notebook indicating the date and time (beginning and ending) of the calibration and maintenance procedures.

RECORD READINGS:

4.4.1 Wind Direction Sensor

4.4.1.1 Sensor Checks

LINEARITY CHECK

The wind direction sensor linearity check includes the following procedures:

- Attach the wind direction vane angle bench stand to the wind direction sensor.
- Position the vane into 45° increments using the vane angle bench stands 0° – 360° scale.
- Record the DAS values at each increment.

STARTING THRESHOLD CHECK

The sensor bearing starting threshold check includes the following procedures:

- Remove the propeller from the shaft.

- Install the torque sensor on top of the anemometer with the string out toward the propeller shaft.
- Pull the string clockwise (counterclockwise) around the full 360º range of motion. The amount of torque it takes to move the instrument should not exceed the threshold given for that instrument.

4.4.1.2 Sensor Adjustments and Maintenance

If checks are beyond the following designated values, as designated in Table 1, perform the following adjustments:

ORIENTATION: Re-orient the sensor if the alignment check indicated is greater than ± 5° difference at any point by:

- Loosening the alignment collar on the tripod mast.
- Aligning the wind direction vane to known landmark.
- Twisting the collar until the designated azimuth is achieved.
- Tightening the alignment collar.

LINEARITY: Replace the potentiometer if the linearity check indicates greater than 5° deviation from the suggested values. Consult the manufacturer's instruction manual for the proper procedure.

STARTING THRESHOLD: Replace the bearings if the starting threshold is greater than 6gm-cm. Consult the manufacturer's instruction manual for the proper procedure.

4.4.1.3 Post-Maintenance Calibration Checks

After completing all maintenance and adjustment activities, initiate a post-maintenance calibration check as described in Section 4.3.1, and record them as the post-maintenance values.

4.4.2 Wind Speed Sensor

4.4.2.1 Sensor Checks

MOTOR RESPONSE CHECK

The wind speed sensor speed response check includes the following procedures:

- Keep the PC400 display open that you had open for the previous calibration steps.
- Remove the anemometer propeller (if not already removed) and attach the R.M. Young anemometer drive motor to the sensor input shaft.
- Adjust the calibrator for 600 rpm and allow the sensor to stabilize.
- Repeat the procedure for 1300, 2300, 4000, and 7000 rpm.

Table 3: Wind speed calibration input (rpm) and associated speed values (m/s)

Input (rpm)	Speed (m/s) for 05103 (m/s = rpm*0.00149)	Speed (m/s) for 05305-AQ (m/s = rpm*0.00512)
0	0	0
600	2.93	3.07
1300	6.36	6.64
2300	11.25	11.75
4000	19.56	20.44
7000	34.23	35.77

STARTING THRESHOLD CHECK

The propeller starting threshold check includes the following procedures:

- Remove the sensor.
- Attach the torque disc to the anemometer shaft.
- Note the weight required to overcome the shaft rotational threshold. (If a 1gm screw is placed 1cm from the center of the torque disk, the propeller torque is 1gm-cm.)
- The starting threshold of the sensor's anemometer shaft should not be greater than 1gm-cm.

4.4.2.2 Sensor Adjustments

To calibrate the wind system electronics using a signal from the instrument, temporarily remove the propeller and connect the Model 18801 or 18802 Anemometer Drive to the propeller shaft. Apply the appropriate calibration formula to the calibrating motor rpm and adjust the electronics for the proper value. For example: with the propeller shaft turning at 3600 rpm on the 05305-AQ, adjust an indicator to display 18.4 meters per second (3600 rpm x 0.00512 m/s/rpm = 18.4 m/s)

4.4.2.3 Sensor Maintenance

If checks are beyond the designated values, as designated in Tables 1 and 2, perform the following maintenance:

SENSOR RESPONSE: Inspect the sensor chopper disc and clean if necessary. Replace the sensor if response remains beyond tolerance.

STARTING THRESHOLD: Replace the sensor bearings of the starting threshold is greater than 3 gm-cm.

4.4.2.4 Post-Maintenance Calibration Checks

After completing all maintenance and adjustment activities, initiate a post-maintenance calibration check as described in Section 4.3.2 and record them as post-maintenance activities.

4.5 Troubleshooting

The potentiometer has a life expectancy of fifty million revolutions. As it becomes worn, the element may begin to produce noisy signals or become nonlinear. If signal noise or non-linearity becomes unacceptable, replace the potentiometer, following the instructions given in the manufacturer's instruction manual.

5.0 RM YOUNG MODEL 107-L AND 109-L TEMPERATURE PROBES

According to the instrument manual, "The 109 Probe requires minimal maintenance. Check monthly to make sure the radiation shield is free from debris. All instruments will be checked before and after deployment, when data are downloaded from the dataloggers, and before equipment removal at the end of the field study, according to the *Station Monitor Checklist*.

For all factory repairs and recalibrations, customers must get a returned material authorization (RMA). A "Declaration of Hazardous Material and Decontamination" form must be filled out and all requirements specified in it must be complied with. This is true for all equipment from Campbell Scientific.

5.1 Equipment and Supplies

- R.M. Young Model 109-L (107-L) Temperature Probe
- The instrument's associated datalogger (CR206 for the 109-L, and CR850 for the 107-L)
- Field notebook
- Laptop with PC400 software installed
- Three water baths, one cold, one room temperature, and one warm
- A Traceable Digital Thermometer from VWR Scientific Inc. #7238 (For calibration comparison. The thermometer used for this audit was certified on 5/21/2010 by Chinook Engineering.)

5.2 Probe Specifications

The Model 109-L Probe uses a BetaTherm 10K3A1 thermistor to measure temperature. It is designed for use with the CR200(X) series datalogger. The probe has a temperature range of -50°C to +70°C and has a maximum error of ±0.6°C over the operating range.

The Model 107-L Probe uses a BetaTherm 100K6A1B thermistor to measure temperature. This probe has a temperature range of -35°C to +50°C and has a tolerance of ±0.2°C over the operating range.

The time constant in air is between 30 and 60 seconds in a wind speed of 5 m s^-1. This study

will be recording 1-minute averages based on 10-second observations, and storing 15-minute, 60-minute, and daily averages.

5.2.1 Sensor Check

Prepare three water baths, a cold water bath with ice (temperature near 0°C), a room temperature bath (around 20°C), and a warm water bath (around 40°C). Make sure the water baths are deep enough to submerge both the control and test sensors.

Attach the temperature sensor to its corresponding datalogger (CR850 for 107 probe, and CR206 for 109 probe). For the 107-L, simply attach the wiring plug to the plugin on the bottom of the housing box. The 109-L must be connected to the datalogger following the wiring diagram in Figures 1 and 2 in the SOP Appendix. Then connect the datalogger to the field laptop, using the RS-232 cable and adapter (if needed). As before, once you have connected to the appropriate datalogger, go to the "Monitor Data" tab so you can see the data update every 10 seconds.

Tie together the control temperature sensor and the test sensor with an elastic band, and submerge them in the first water bath. Wait approximately one minute until the output temperatures begin to stabilize (the control sensor will have a much faster time constant than either the 107 or 109 temperature probes). Then note both the control and the DAS temperatures on the calibration sheet. Repeat this for the remaining two water baths.

The measured temperature should not deviate from the calibration temperature by more than 1ºC.

6.0 DOCUMENTATION

CALIBRATION FORMS: Calibration forms should be completed entirely. The user will review and initial all calibration forms.

LOG NOTES: A summary of results and maintenance performed must be included in the field notebook. Note any abnormalities in sensor or calibration operation that could affect the quality of data.

7.0 REFERENCES

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University of Wyoming
Upper Green River Basin Ozone Wind Field Investigation (O3w)

Equipment Installation
Standard Operating Procedure 02

May 2012

Title	Name	Signature
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1.0 PURPOSE AND APPLICABILITY

Proper set up of equipment and instruments is crucial to gathering data correctly. There are two parallel sets of instructions, one set for the mesonet sites using equipment from 2008, which includes a CR206 datalogger housed in a large cooler on the ground, a 05305-AQ wind monitor, and a 109-L temperature sensor. The newer system from 2010 includes a CR850 datalogger housed in a box which is mounted on the tripod mast, a 05103 wind monitor, and a 107-L temperature sensor.

Section 2.0 of this SOP gives instructions on how to select appropriate sites for the mesonet equipment. Section 3.0 details how to install the RM Young Model 05103 and 03503-AQ Wind Monitors, and Section 4.0 provides instructions on how to install the RM Young model 107-L and 109-L Temperature Probes. Finally, Section 5.0 gives instructions on how to install the CR206 datalogger, as no setup is needed for the CR850 datalogger.

1.1 Mesonet Site Selection

Citing the mesonet tripods correctly is an essential aspect of this project because it ensures that measurements are as unaffected as possible by small-scale forces, such as buildings and obstacles that might cause unnecessary variations in the data. This control is necessary to ensure that measurements are not biased and reflect local topographical conditions. Furthermore, the RM Young Model 05103 and 05305-AQ Wind Monitors operate as a vane; therefore it is extremely important that the tripod tower be level and situated on firm, “natural” ground.

For wind monitoring, the site should be located at least four times as far away as the height of nearby obstructions. This will lessen small-scale turbulent effects that would only add noise to the wind and temperature measurements.

For temperature monitoring, the characteristics of the surface on which the mesonet is placed can have a large effect on the temperature of the air above it. For example, large areas of concrete or asphalt should be avoided, as they heat up faster than the ground around it. Consequently, the RM Young Model 107-L and Model 109-L temperature probes should be located on the type of surface that represents the local surface characteristics, and at least 30 m from large paved areas.

1.2 Wind Monitor Installation

It is important that the RM Young model 05103 and 05305-AQ wind monitors be installed correctly to avoid bias in the wind measurements. Using this SOP and the *RM Young Model 05305-5 Wind Monitor-AQ Manual*, from which much of the instructions were taken, a person should be able to install the instrument correctly.

The sensor mounts on standard one-inch pipe, (OD 35mm, 1.34”). An orientation ring is provided to ensure proper realignment, and a stainless steel band clamp secures the mounting post assembly and orientation ring to the pipe. A junction box at the base of the instrument merges the electrical connections and signal cable to the signal conditioning, display, and recording devices.

Initial installation is most easily done with two people; one to adjust the orientation ring and the other to observe an indicating device, such as a GPS, to verify the orientation. After initial installation and orientation, the instrument can be removed and returned to its mounting without realigning the vane since the orientation ring preserves the wind direction reference.

Grounding the Wind Monitor is also important. Without proper grounding static electrical charge can build up during certain atmospheric conditions and discharge through the transducers. This discharge can potentially cause erroneous signals or transducer failure. To direct the discharge away from the transducers, the mounting post assembly in which the transducers are mounted is made with a special antistatic plastic. Therefore it is very important that the mounting post be connected to a good earth ground.

2.0 MESONET SITE SELECTION

2.1 Summary of the Method

Mesonet sites should be located at least twice, ideally six times, as far away as the height of the nearest obstacle on a flat surface other than asphalt. This is important because asphalt tends to heat up faster than the natural surface of the ground, causing unwanted local heating effects.

2.2 Equipment and Supplies

- Local topographical map and road map
- GPS
- A vehicle
- Flags (to mark the mesonet location)
- Potential Site list, as defined in Table 1 of the QAPP
- Permissions to venture onto property

2.3 Procedural Steps

- Look for pre-selected locations on the potential site list.
- Use the GPS to locate a potential mesonet site shown on the map.
- Microsite the specific mesonet site location based on the local terrain.
- Place a flag at the location designated for the mesonet site.
- Note the GPS coordinates in the field notebook.

2.4 Data and Records Management

The GPS coordinates of the finalized mesonet sites will be kept by Brittni Emery and a map of final locations will be made using Google Earth. Emery will also maintain all records of permission to go on property.

3.0 EQUIPMENT INSTALLATION

3.1 Equipment and Supplies

- GPS and map of site locations
- All mesonet equipment (tripod, battery, cooler, solar panel, wiring, RM Young model 107-L and 109-L temperature probes and radiation shield, RM Young Model 05103 and 05305-AQ Wind Monitor, and all associated hardware)
- Tools (1/2" open end wrench, Phillips screw driver, pliers, etc.)
- UV resistant cable ties
- RF401 radio
- Field laptop
- RS-232 cable (with adapter)

3.2 Procedural Steps

- Travel to a mesonet site, bringing with all necessary equipment.

- Set up a tripod over the mesonet site location marked previously, leaving the marker in place in case the mesonet were to be moved for any reason. The tripod should be staked into the ground to avoid instrument damage in the event of strong winds.

- Install the solar panel and connect it to the battery. The battery will be housed in the cooler, located next to the tripod for the systems with the CR206 dataloggers.

- Install the temperature probe according to the wiring diagram produced in Section 3.3.4 of SOP 01.

- Install the CR206 datalogger according to Section 3.3 of this SOP.

- Install the RM Young Wind Monitor according to Section 3.4 of this SOP.

- Install the temperature probe according to Section 3.5 of this SOP.

- Once all instruments have been properly installed, calibrate the wind monitor according to Section 4.0 of SOP 01. The final set up should look similar to Figure 3 in the SOP Appendix.

3.3 CR206 Datalogger Installation

- Attach the antenna to the "Antenna" connector on the CR206.
- The CR206 and power source will be housed in a cooler located on the ground next to the mesonet tripod.
- Connect 12 DVC external power source to the CR206 by inserting the positive lead into the "Battery +", as seen in Figure 1 of the SOP Appendix.

- Insert the negative lead into the “Battery -”, again, as seen in Figure 1 of the SOP Appendix.
- Make sure the datalogger is properly grounded, by connecting the “Ground Lug” port on the datalogger (see Figure 1 in SOP Appendix) to an earth ground. Specifically, there is a screw terminal on the tripod mast where a ground cable can be connected between the datalogger and the mast. The stakes holding the tripod in the ground will act as the grounding device.
- Make sure that the RF401 can communicate with the CR206 by opening the PC400 software on the laptop and pressing the “Connect” button and selecting the proper site name.

3.4 Wind Monitor Installation

After the instruments have been unpacked, the Wind Monitor should be checked according to Section 4.4 in SOP 01.

Install the Wind Monitor following these steps:

1. Mount Wind Monitor
    a. Place orientation ring on mounting post. DO NOT tighten band clamp yet.
    b. Place Wind Monitor on mounting post. DO NOT tighten band clamp yet.
2. Connect Sensor Cable
    a. Slide junction box cover up.
    b. Route cable thru strain relief opening at bottom of junction box. Secure cable by tightening packing nut.
    c. Slide junction box cover down.
    d. Connect sensor cable to terminals. For model 05305-AQ monitors, see wiring diagram in Figure 2 in the SOP Appendix. For model 05103 monitors, simply connect the plug at the end of the cable to the socket at the bottom of the housing box.
3. Align Vane
    a. At this point, the instrument should be connected to the datalogger. Connect the field laptop to the datalogger and open PC400. Connect to the correct datalogger and monitor the data.
    b. Using a GPS compass, start at the tripod mast and walk south.
    c. Another person, sighting down the instrument centerline, points the nose cone at the person with the GPS.
    d. While holding vane in position, slowly turn the instrument base until the datalogger shows the proper value, in this case, 180º.
    e. Tighten mounting post band clamp on the instrument base.
    f. Engage orientation ring indexing pin in notch at instrument base.
    g. Tighten orientation ring band clamp.
4. Ground the Wind Monitor
    a. Inside the wind monitor junction box, the terminal labeled EARTH GND is internally connected to the antistatic mounting post. This terminal should be

connected to an earth ground terminal on the datalogger. It does not matter which ground terminal is used.

3.5 Model 107-L and 109-L Temperature Probe Installation

- The 107-L (109-L) must be housed inside a radiation shield when used in the field. The Radiation Shield has a U-bolt for attaching the shield to the tripod mast.
- The temperature probe is held within the radiation shield by a mounting clamp on the bottom of the radiation shield. Loosen the two mounting clamp screws, and insert the sensor through the clamp and into the shield. Tighten the screws to secure the sensor in the shield and route the sensor cable to the datalogger. Secure the cable to the tripod using cable ties.
- Connect the 109-L temperature sensor to the datalogger using the wiring diagram provided in Figures 1 and 2 of the SOP Appendix. The 107-L probe connects to the housing box the same way as the wind monitor does, as the two cables are attached to the same plug.
- If any questions arise, refer to the diagram on page 4 of the *Model 109 Temperature Probe* manual.

4.0 TROUBLESHOOTING

RF401 to CR206 Communications:

- If the radio connection is not working, refer to Section 2.0 of SOP 01.
- If the radio connection is still not working, connect the RS-232 cable between the "RS-232" port on the CR206 and the RS-232 port on the PC. This will also allow for direct access to the CR206.

5.0 REFERENCES

Campbell Scientific, Inc., Instruction Manual: 05103, 05103-45, 05106, and 05103 R.M. Young Wind Monitors. Revision 10/10. Copyright 1984-2010.

Campbell Scientific, Inc., Instruction Manual: Model 107 Temperature Probe. Revision 11/11, Copyright 1983-2011.

Campbell Scientific, Inc., Instruction Manual: Model 109 Temperature Probe. Revision 7/11, Copyright 1983-2011, Logan, UT.

R.M. Young Company, Model 05305-5 Wind Monitor- AQ. Manual PN 05305-5-90. Traverse City, Michigan.

Title: Site Visit, Data Collection, and Equipment Maintenance SOP
Number: 03
Revision: 3.0
Date: May 2012

University of Wyoming
Upper Green River Basin Ozone Wind Field Investigation (O3w)

Site Visit, Data Collection, and Equipment Maintenance
Standard Operating Procedure 03

May 2012

Title	Name	Signature
Principle Investigator	Brittni Emery	
Project Manager	Dr. Robert Field	

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1.0 PURPOSE AND APPLICABILITY

After the mesonet has been installed and is recording data as per SOP 02, data will be downloaded and sites will be checked on a bi-weekly or monthly basis, as weather permits, according to the present SOP. Data from the CR06 mesonet systems will be downloaded on a bi-weekly basis due to limited data storage capabilities, while data from the CR850 systems can be downloaded on a monthly basis.

Using a standard method of data collection will help reduce errors that might have otherwise been caused from inconsistencies in the style of data collection. It also aids personnel in knowing what steps to take if they are otherwise unfamiliar with the data acquisition process.

It is possible that mesonet sites could become inaccessible during the study period. If that occurs to the Burma, Speedway, Two Rivers, Cottonwood Creek, or Trapper's Point sites, and it is possible for personnel to drive to within one mile of the mesonet site with no obstacles between the RF401 radio and the datalogger, the radio signal will reach the datalogger. The only implication is that the mesonet site will not be able to be inspected during that download period. If either the Buckhorn, Dry Piney, Riverside, Trapper's Point, or Mesa sites become inaccessible during the study period, the data will not be downloaded at that time. But because the CR850 dataloggers have a 4mb data capacity, the data will be able to be collected during the next collection period without any data loss. Because of the large amounts of snowfall that occur in the UGRB, it is also possible that long periods of snow covering the solar panels could cause an interruption of the dataset. If this occurs, it will not be known until the next site visit. But if personnel see evidence of snow covering the solar panel, will be cleared immediately, and a note of the event will be made in the field notebook.

2.0 EQUIPMENT AND SUPPLIES

- RF401 Radio
- RS-232 to Serial Adapter
- Field Laptop
- Field Notebook

3.0 PROCEDURAL STEPS

Note: Make sure the field laptop is fully charged before venturing out.

Enter the arrival time at the site in the field notebook.

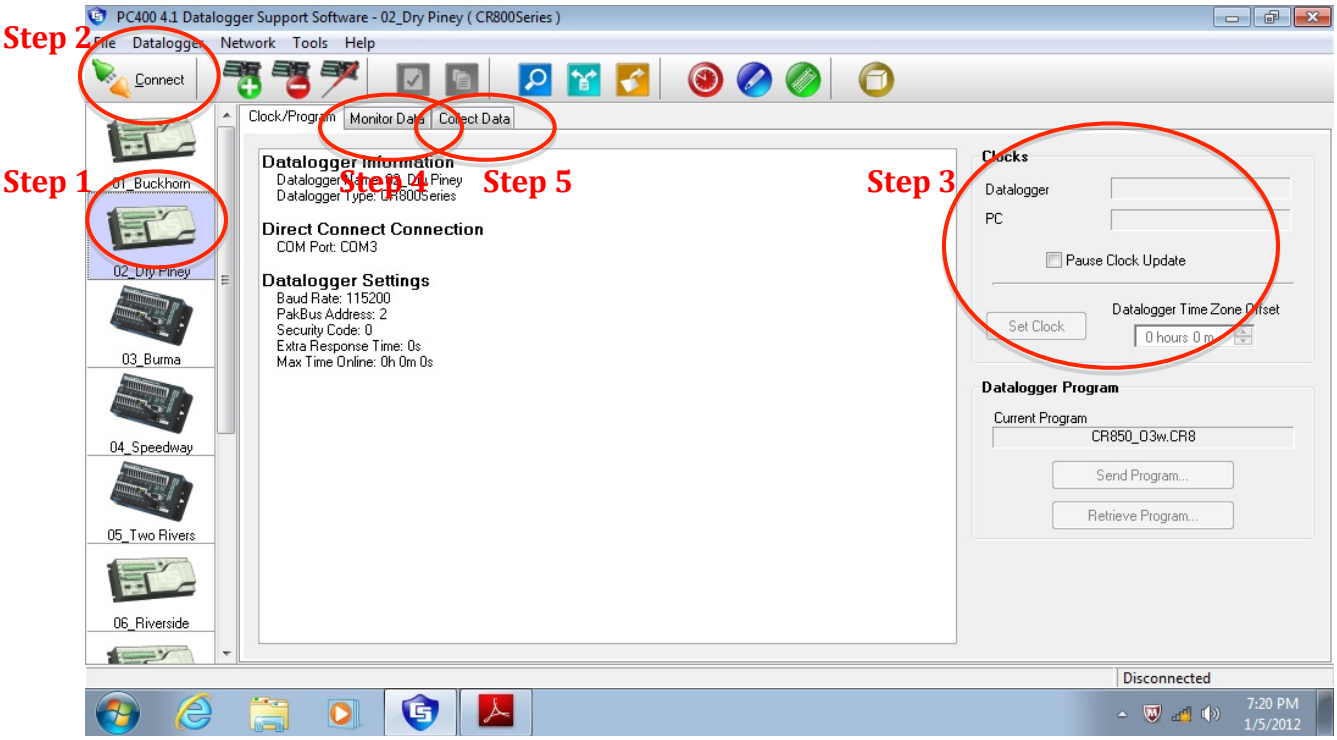
Connecting to the Burma, Speedway, Two Rivers, Cottonwood Creek, and Trapper's Point sites (bi-weekly download):

Attach the RS-232 to Serial Adapter between the field laptop and the RF401 radio.

When parked within radio range of a desired site, open PC400, select the appropriate site from the side bar, and press the "Connect" button on the main toolbar. Figure 1 shows the PC400

screen as it will look when the program is opened, and a map of sites and site names is provided in Appendix A.
Figure 1: PC400 Homescreen

Step 1: Select Datalogger
Step 2: Connect
Step 3: Check Time (Section 3.1)
Step 4: Monitor Data and verify realistic conditions (Section 3.2)
Step 5: Collect Data (Section 3.3)



NOTE: If the radio connection is not working, first, close and reopen PC400, the program may have frozen. If it is still not working, restart the computer. The last resort is to connect the RS-232 cable directly between the RS-232 port on the CR206 and the serial port on the PC. This will also allow for direct access to the CR206. Note any issues in the field notebook and report to Brittni Emery.

Connecting to the Buckhorn, Dry Piney, Riverside, Trapper's Point, and Mesa Sites (monthly download):

Walk to the tripod, open the box that houses the CR850 datalogger and battery, and connect the RS-232 cable directly between the RS-232 port on the CR850 and the serial port on the PC. Then connect as you would to the bi-weekly sites.

3.1 Check Time

When connected, verify the time on the data logger is within 1 minute of the computer time. If

the times differ by more than one minute then synchronize the data logger clock to the computer by clicking the "Set Clock" button.

3.2 Compare current measurements to your observations of ambient conditions.

Click on the "Monitor Data" tab to view the latest values.

Write down the latest values for the following measurements in the station log book: temperature, wind speed, wind direction, and battery voltage.

Observe the conditions outside. Compare what you see with the meteorological readings on the datalogger. Does it make sense? If not, enter your observations in the field notebook and send an email to Brittni Emery (bemery2@uwyo.edu). The following tables may help.

Remember: The wind direction is reported as the direction the wind is blowing from.

Temperature	
°C	°F
-40	-40
-30	-22
-20	-4
-10	14
0	32
10	50

Wind Speed	
m/s	mph
0.5	1.1
1.0	2.2
5.0	11.2
10.0	22.4
15.0	33.6
20.0	44.7

3.3 Collect data

Click on the "Collect Data" tab and make sure that the "What to Collect" box has a check by "New data from datalogger". Press the "Collect" button and wait for the complete download. This should take approximately 15 minutes for the bi-weekly sites, and less than 1 minute for the monthly sites.

Note the date, and start and stop time of the data collection in the site logbook.

When data has finished downloading, click the 'ok' button in the window that will appear, and then press the "Disconnect" button in the upper-left corner of the screen.

The mesonet equipment should also be checked according to the following instructions during this time.

3.4 Inspect sensors for physical damage.

From the ground, inspect the R.M. Young wind sensor propeller/vane assembly. Look for damage to the propeller and make certain that the propeller is turning smoothly. Also, look for other circumstances that could affect data validity, such as an accumulation of ice.

Inspect the temperature sensor. Look for damage to the radiation shield. Watch for dust or liquid accumulation inside the radiation shield or on cabling. Also, look for other circumstances that could affect data validity, such as an accumulation of ice and snow on the radiation shield.

Report any damage to Brittni Emery via email and enter your observations in the field notebook.

Title: Mesonet Station Data Handling Procedures SOP
Number: 04
Revision: 3.0
Date: May 2012

University of Wyoming
Upper Green River Basin Ozone Wind Field Investigation (O3w)

Mesonet Station Data Handling Procedures
Standard Operating Procedure 04

May 2012

Title	Name	Signature
Principle Investigator	Brittni Emery	
Project Manager	Dr. Robert Field	

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1.0 PURPOSE AND APPLICABILITY

After mesonet data have been collected according to SOP 03, the following instructions describe the steps to transfer, back up, compile, quality assure and validate them.

In addition to the mesonet data, meteorological data will be gathered from the Pinedale Airport, the Big Piney NWS site, Remote Automated Weather Stations (RAWS), Snow Telemetry (SNOTEL) sites, the UW mobile laboratory, and Wyoming Department of Environmental Quality (WDEQ) continuous monitoring sites.

This project will employ a two-level data validation process. These levels and data quality assurance/quality control (QA/QC) steps are defined as follows:

Data Compilation: After data have been acquired from the dataloggers at each mesonet station in the field, separate data files from each station will be compiled together to form one continuous data file for each station. This will include filling in missing time values. While 1-minute, 5-minute, hourly and daily data files are available, it is the minutely data files that will be used for quality assurance. Compiled data have not been trimmed at the beginning or end of the files, no procedural adjustments for calibration changes have been applied, nor have bad data been flagged.

Level 1: These data have been edited to promote data quality. The general features of Level 1 are: 1) time corrections with reference to field computer time; 2) flagging measurements with respect to site visit notes and log data sheets; 3) removal of data at beginning and end of data files to remove inapplicable data.

Level 2: 1) performing of internal consistency tests; 2) plot data in Excel, and look for and correct data inconsistencies and/or missing data.

Internal Audit: Perform an internal audit of the equipment used during the project. The information can be used to determine whether the data need to be adjusted in order to promote data quality.

Note: New data files will be created for each step in the data QA/QC process to avoid or alleviate potential errors or mistakes that may occur. This will result in compiled files, time corrected files, flagged and trimmed files, and level 2 files. Data from the internal audit will be stored in a separate Excel workbook.

Data Summary Report: Produce a data summary report, which includes a description of the project, the methodology used, a summary of the data at each site, and an appendix containing the results of the internal audit and the SOPs created for this project.

2.0 EQUIPMENT AND SUPPLIES

- Flash drive
- Computer equipped with Microsoft Excel

3.0 DATA TRANSFER AND BACKUP

All mesonet data will be copied from the field computer to the M://bemery2 server at UW using a flash drive. This flash drive will also be used as a backup for the mesonet data.

4.0 DATA COMPILATION

Mesonet data files will be output in TOA5 format, a comma separated format with headers. This format can be read into Microsoft Excel to perform data quality checks. Each averaging period, 1-minute, 5-minute, 1-hour, and daily averages, are stored in separate files, and for the following quality assurance checks, the minutely data files from each station will be used.

Data for the project were downloaded every two weeks for several of the dataloggers, and monthly for the rest. This resulted in several minutely data files for each mesonet station. These files can be combined in Microsoft Excel to create one continuous data file for each station and time stamps should be inserted for known periods of missing data.

5.0 LEVEL 1 DATA VALIDATION

Level 1 data validation refines the data by referencing the data collection sheets and flagging bad data values, correcting time stamps for events such as daylight savings time and instrument time drift, and trimming the beginning and end of the data files to remove any inapplicable data that may have been collected while the instruments were being set up and taken down.

5.1 Documentation

5.1.1 The Data Validation Log

The Data Validation Log is used to track the completion of each major step of the validation process and when it occurred. This comprises one section of an electronic spreadsheet called Thesis_Completion_Steps_detail.xlsx, and is kept by Brittni Emery.

5.1.2 O3w Data Summary

The O3w Data Summary is an electronic diary of site-related events such as instrument malfunctions and repairs, data adjustments, calibrations, weather episodes, etc., that may be relevant to data validation. Much of this information will be gathered from notes written in the field notebook and data collection sheets throughout the project.

The data summary contains the site number and name, start and end dates to indicate the time period involved, and a list of the parameters that may have been affected by the event. Another field within the table indicates if the event is considered to be a problem

resulting in loss of data or not. This table will be used to flag the appropriate data within the minutely data files.

5.2 Time Corrections

There were two time periods during O3w where the time was changed; once where the datalogger time exceeded the PC time by one day, and once for daylight savings time. Therefore, it was necessary to go back into the minutely data files and convert the given timestamp to the appropriate time. For any further changes it will be important to make sure which time is being referred to, corrected or uncorrected.

5.3 File Trimming

During the setup and takedown of the mesonet equipment, data were often collected that would be considered inapplicable to the project. These data were removed from the beginning of the files, while data from the end of the files were copied and pasted into a spreadsheet specifically for calibration data, as an internal audit was performed in the field at the end of the project.

6.0 LEVEL 2 DATA VALIDATION

Level 2 data validation further refines the data by performing internal consistency tests, and plotting data, then looking for and either filling in or removing missing or anomalous data values according to the acceptance criteria given in Section 6.2 below.

6.1 Excel Plots

Data should be plotted in Microsoft Excel using the uncorrected time stamps, as it is easier to plot in Excel. Just remember to convert to the corrected time when looking for anomalous values in the data that are seen in the graph. Three plots were made for each site, one for wind speed, one for wind direction, and one for temperature. These plots were then examined for anomalous and missing data. The missing times were filled in, while the anomalous data were flagged, and then removed.

6.2 Validation Acceptance Criteria

The methods for determining if a data value meets validation acceptance criteria are usually related to one of the following events or limitations (specific criteria for each parameter is presented in Table 1 below):

- Data are out of instrument specifications.
- Data exceed minimum or maximum expected value.
- Station temperature is out of specified limits.
- Data are affected by calibration check.
- Less than 45 minutes of data are available for the hourly averaging period

- Instrument or datalogger was affected by acts of nature.
- Instrument or datalogger was affected by power failure.
- Data capture was affected by power failure.
- Data were affected by operator maintenance or calibration check.
- Data were affected by site operator error.
- Data were affected by instrument malfunction or failure.
- Data were below lower detectable limit.

Table 1: Validation Acceptance Criteria for Meteorological Parameters			
Parameter	**Calibration Method**	**Criteria**	**Validation Criteria**
Wind Speed	Selectable speed rpm motor	Max Error	≤ ±0.5 m/s for values <5.0 m/s ≤ ±5.0% for values >5.0 m/s
Wind Speed Starting Threshold	Weighted torque Disk	Max Error	≤ 1 gm-cm
Wind Direction Linearity	45° increment inputs	Max Error	≤ ±5°
Wind Direction Threshold	Weighted Torque Disk	Max Error	≤ 11 gm-cm
Temperature	Traceable Digital Thermometer	Max Error	≤ 1°C

7.0 INTERNAL AUDIT

At the end of the project, immediately prior to mesonet disassembly, an internal audit was performed on the wind monitors, according to the instructions described in Section 4.0 of SOP 01. All of the temperature sensors were audited according to the instructions described in SOP 01.

The audit values were then examined for accuracy according to the limits specified in SOP 01 by Table 2 for the wind monitors, and the end of Section 5.2.1 for the temperature probes. The audit values were also plotted against the input/calibration values on a xy plot and a line of best fit was generated, providing slope, intercept, and R^2 values. These graphs and values will be provided in the data summary report and will be used to determine whether the data need to be adjusted due to calibration issues.

8.0 DATA SUMMARY REPORT

A data summary report will be submitted upon the completion of data cleaning. This report will include the following:

- Project overview
- Methodology

- Results
- Appendix:
    - SOPs
    - Internal Audit results

9.0 REFERENCES

United States Environmental Protection Agency, Guidance on Environmental Data Verification and Validation. EPA QA/G-8, Washington, DC, November 2002. Available from: http://www.epa.gov/QUALITY/qs-docs/g8-final.pdf. Accessed August 31, 2011.

A2: WDEQ-AQD EXTERNAL AUDIT REPORT

Note: The U.S. 191 site mentioned in the report refers to the Speedway site, and the New Fork site mentioned refers to the Riverside site.

2012 QUALITY ASSURANCE AUDIT REPORT

for the

UNIVERSITY OF WYOMING UPPER GREEN RIVER BASIN OZONE WIND FIELD INVESTIGATION

Prepared for
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SECTION 1

INTRODUCTION

March 6, 2012, the Wyoming Department of Environmental Quality - Air Quality Division (WDEQ_AQD) conducted performance audits of the meteorological monitoring equipment established during the Upper Green River Basin Ozone Wind Field Investigation in Sublette County. The University of Wyoming operated the meteorological monitoring stations in cooperation with WDEQ-AQD during the 2012 Upper Green River Ozone Study to determine wind field patterns. The stations and variables audited are shown in Table 1-1.

Immediately following the field audits a debriefing was performed with the station operator that summarized the audit results and identified any needed actions.
This report formalizes the audit findings. The audits were conducted in accordance with the most current guidance available from the USEPA. This included guidance provided in the document *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV, Meteorological Measurements*(USEPA, 2008), *Meteorological Monitoring Guidance for Regulatory Modeling Applications* (USEPA, 2000) and appropriate requirements in the Code of Federal Regulations for the operation of meteorological monitoring stations.

This report is divided into five sections. Section 1 provides this introduction. Section 2 describes the audit equipment. Section 3 presents the procedures used in the performance audits. Section 4 provides the criteria used in evaluating the audit results. Section 5 presents the audit results, recommendations and comments by site and includes the detailed audit reports.

SECTION 2

DESCRIPTION OF AUDIT EQUIPMENT

Equipment used in the audit is described below.

METEOROLOGICAL

R.M. Young Selectable Speed Anemometer Drive
To audit the wind speed sensor various known speeds of rotation were obtained using a R.M. Young Model 18802 anemometer drive serial number CA 03609. The rate of rotation is digitally controlled and the certification verified using either a frequency counter or phototachometer.

R.M. Young Vane Angle Fixture – Tower Mounted
The model 18212 Vane Angle Fixture is used for wind direction indication of wind monitor systems. Pointer indicates 0 to 360 degrees with ½ degree resolution.

Magellan Explorist 400 Global Positioning System (GPS)
A Magellan Explorist 400 12-channel GPS receiver, serial number 11905112018, was used to walk the direction of the wind direction cross arm and determine the pointing angle. The GPS receiver can be read to an accuracy of approximately ±0.5°and has the ability to automatically correct for true north reading.

Control Company Traceable Digital Temperature Probe
A Control Company precision thermistor temperature probe model 4000, serial number 101477029, was used to audit the temperature sensor. The probe is certified against a NIST - traceable mercury in glass thermometer.

SECTION 3

METEOROLOGY

Wind Speed
The wind speed audit begins with the inspection of the propeller to ensure that it is intact. The propeller is then removed to produce a zero point. Next, the R.M. Young selectable speed anemometer drive is connected to the sensor shaft to simulate wind speeds of approximately 2.56, 7.68, 12.80, 23.04, and 33.28 m/s. The data logger responses are compared to the calculated actual values and the differences compared to the audit criteria. The sensor bearings are then checked for excessive wear by manually turning the sensor shaft to determine whether there is any bearing drag. The R.M. Young Model 18310 torque disc is then mounted on the sensor shaft. The starting torque is determined using the manufacturer-provided “k” value to determine the effective wind speed starting threshold.

Wind Direction
The wind sensor cross-arm relative to true north is checked using a GPS unit.
The GPS walk off method described in Baxter (2001) was used to determine the arm direction. The wind direction vane is then pointed down the cross-arm to determine the vane reading when pointing along the arm. For RM Young sensors, the vane is then rotated in increments of 45° with respect to the cross arm using an RM Young wind direction calibration jig. The responses of the data logger are noted and differences calculated. The difference calculated for each input wind direction is then compared with the audit criteria. The starting threshold of the sensor is checked using an R.M. Young model 18331 wind direction torque gauge. This torque is used with the manufacturer supplied vane “k” value to determine the effective wind direction starting threshold.

Temperature
The temperature-sensing system is audited by immersing the system sensor and an NIST-traceable audit thermometer in the same water bath and comparing the readings of the thermometer with the data logger and chart recorder outputs at approximately zero, 20° and 40° C. The difference calculated for each point is compared with the audit criteria.

SECTION 4

PERFORMANCE AUDIT CRITERIA

Measurement Variable	Audit Criteria	Procedure Reference	General Procedure
Horizontal Wind Speed	Accuracy ±0.25 m/s ≤5 m/s; ±5%> 5m/s not to exceed 2.5 m/s	EPA-454/B-08-002	Five wind speeds within the expected range of operation
Horizontal Wind Direction	±5º; includes orientation error	EPA-454/B-08-002	4 to 8 points equally spaced around the compass are compared. If any points are outside of criteria then corrective action is necessary. Sensor alignment is verified using GPS method.
Temperature	±1.0ºC	EPA-454/B-08-002	Three temperatures within the expected range of temperatures (0-40ºC)

Due to the unavailability of the R.M. Young Model 18310 torque disc, and the R.M. Young model 18331 wind direction torque gauge the AQD auditor did not perform these evaluations of the monitoring equipment.

Section 5
5.1 US 191
5.1.1 Site Location

The site is located at 42.55535 North Latitude and -109.612 West Longitude (GPS).

5.1.2 Station Equipment Summary

RM Young Model 5305 Wind Monitor AQ: Sensor is capable of monitoring wind speed and wind direction. This sensor is mounted on a 3-meter tripod resulting in a measurement height of 3 meters.
Campbell Scientific 109-L Temperature Probe: The thermistor is housed within a naturally aspirated radiation shield and has a measurement range of -50º to +70ºC.
Campbell Scientific CR206 Data Logger: Measures the sensors, processes the results and transmits the data via a 915 MHz radio, allowing remote accessing and downloading of data.
A solar panel allows for continuous monitoring. All equipment is housed in an insulated container. A 110 amp-hour deep cycle 12-Volt battery is used to power the equipment.

5.1.3 Audit Results

Audit Record

WDEQ AQD
122 W. 25th Street
Herschler Building, 2E
Cheyenne, WY 82002

Horizontal Wind Speed

Date: 6-Mar-12
Start: 1100
Finish: 1145
Auditor: Steve Mugg
Witness: None

Site Name: US 191
Operator: Brittni Emery, UW
Project: Upper Green River Basin Ozone Wind Field

Manufacturer: RM Young
Serial No.: Not Recorded
Last Calibrated: December 2011

Model: 5305 Wind Monitor
Sensor Ht.: 3m

Audit Point	Input m/s	DAS m/s	Difference m/s	Difference %
1	0.00	0.00	0.00	
2	2.56	2.42	0.14	

Audit Criteria: ±.25 m/s: ws ≤ 5 m/s

Audit Point	Input m/s	DAS m/s	Difference m/s	Difference %
3	7.68	7.85		2.21%
4	12.80	12.74		-0.47%
5	23.04	23.30		1.13%
6	33.28	33.05		-0.69%

Audit Criteria: ± 5%: ws > 5 m/s

Comments:

Audit Record

Horizontal Wind Direction

WDEQ AQD
122 W. 25th Street
Herschler Building, 2E
Cheyenne, WY 82002

Date:	6-Mar-12	**Site Name:**	US 191
Start:	1100	**Operator:**	Brittni Emery,UW
Finish:	1145	**Project:**	Upper Green River Basin Ozone Wind Field
Auditor:	Steve Mugg		
Witness:	None		
Manufacturer:	RM Young	**Model:**	5305 Wind Monitor
Serial No.:	Not Recorded	**Sensor Ht.:**	3m
Range:	0-355°		
Crossarm:	180°		
Last Calibrated:	December-12		

Audit Point	Degrees Reference	Degrees DAS	Difference Degrees
1	45	44.806	-0.194
2	90	88.303	-1.697
3	135	132.266	-2.734
4	180	177.457	-2.543
5	225	223.073	-1.927
6	270	267.726	-2.274
7	315	313.685	-1.315
8	0	0.078	0.078

Audit Criteria ± 5 Degrees

Comments:

Audit Record

Ambient Temperature

WDEQ AQD
122 W. 25th Street
Herschler Building, 2E
Cheyenne, WY 82002

Date:	6-Mar-12	**Site Name:**	US 191
Start:	1100	**Operator:**	Brittni Emery, UW
Finish:	1145	**Project:**	Upper Green River Basin
Auditor:	Steve Mugg		Ozone Wind Field
Witness:	None		
Manufacturer:	Campbell Scientific	**Model:**	109-L Temperature Probe
Serial No.:	Not recorded	**Sensor Ht.:**	3m
Lower Range:	-50 **Deg C**		
Upper Range:	70 **Deg C**		
Last Calibrated	December-12		

Audit Point	Input Degrees C	DAS Degrees C	Difference Degrees C
1	0.002	0.001	-0.001
2	20.874	20.804	-0.070
3	43.497	43.629	0.132

Audit Criteria ± 1.0 Degrees Celsius

Comments:

5.2 New Fork

5.2.1 Site Location

The site is located at 42.64642 North Latitude and -109.826 West Longitude (GPS).

5.2.2 Station Equipment Summary

RM Young Model 5305 Wind Monitor AQ: Sensor is capable of monitoring wind speed and wind direction. This sensor is mounted on a 3-meter tripod resulting in a measurement height of 3 meters.

Campbell Scientific 109-L Temperature Probe: The thermistor is housed within a naturally aspirated radiation shield and has a measurement range of -50º to +70ºC.

Campbell Scientific CR850 Data Logger: Measures the sensors, processes the results and transmits the data via a 915 MHz radio, allowing remote accessing and downloading of data.

A solar panel allows for continuous monitoring. All equipment is housed in an insulated container. A 110 amp-hour deep cycle 12-Volt battery is used to power the equipment

5.2.3 Audit Results

Audit Record

WDEQ AQD
122 W. 25th Street
Herschler Building, 2E
Cheyenne, WY 82002

Horizontal Wind Speed

Date: 6-Mar-12
Start: 1100
Finish: 1145
Auditor: Steve Mugg
Witness: None

Site Name: New Fork
Operator: Brittni Emery, UW
Project: Upper Green River Basin Ozone Wind Field

Manufacturer: RM Young
Serial No.: Not Recorded
Last Calibrated: December 2011

Model: 5305 Wind Monitor
Sensor Ht.: 3m

Audit Point	Input m/s	DAS m/s	Difference m/s	Difference %
1	0.00	0.00	0.00	
2	2.56	2.42	0.14	

Audit Criteria: ±.25 m/s: ws ≤ 5 m/s

Audit Point	Input m/s	DAS m/s	Difference m/s	Difference %
3	7.68	7.97		3.78%
4	12.80	12.76		-0.31%
5	23.04	23.52		2.07%
6	33.28	33.61		0.99%

Audit Criteria: ± 5%: ws > 5 m/s

Comments:

Audit Record

Horizontal Wind Direction

WDEQ AQD
122 W. 25th Street
Herschler Building, 2E
Cheyenne, WY 82002

Date:	6-Mar-12	**Site Name:**	New Fork
Start:	1100	**Operator:**	Brittni Emery,UW
Finish:	1145	**Project:**	Upper Green River Basin
Auditor:	Steve Mugg		Ozone Wind Field
Witness:	None		
Manufacturer:	RM Young	**Model:**	5305 Wind Monitor
Serial No.:	Not Recorded	**Sensor Ht.:**	3m
Range:	0-355°		
Crossarm:	180°		
Last Calibrated:	December-12		

Audit Point	Degrees Reference	Degrees DAS	Difference Degrees
1	45	44.925	-0.075
2	90	89.755	-0.2446
3	135	134.776	-0.224
4	180	179.75	-0.25
5	225	223.478	-1.522
6	270	268.5	-1.5
7	315	312.707	-2.293
8	0	0.0478	0.0478

Audit Criteria ± 5 Degrees

Comments:

Audit Record

Ambient Temperature

WDEQ AQD
122 W. 25th Street
Herschler Building, 2E
Cheyenne, WY 82002

Date:	6-Mar-12	**Site Name:**	New Fork
Start:	1100	**Operator:**	Brittni Emery, UW
Finish:	1145	**Project:**	Upper Green River Basin
Auditor:	Steve Mugg		Ozone Wind Field
Witness:	None		
Manufacturer:	Campbell Scientific	**Model:**	109-L Temperature Probe
Serial No.:	Not recorded	**Sensor Ht.:**	3m
Lower Range:	-50 **Deg C**		
Upper Range:	70 **Deg C**		
Last Calibrated	December-12		

Audit Point	Input Degrees C	DAS Degrees C	Difference Degrees C
1	-0.009	-0.023	-0.014
2	20.522	20.865	0.343
3	43.853	43.926	0.073

Audit Criteria ± 1.0 Degrees Celsius

Comments:

A3: CALIBRATION ASSESSMENT

Site Name: Buckhorn **Date:** 4/9/12
Operator: BRE

Horizontal Wind Speed
Instrument Manufacturer and Model: RM Young 05103
Serial Number:

Input (rpm)	Input (m/s)	DAS (m/s)	DAS (m/s)	DAS (m/s)	avg	Difference (m/s)	Difference (%)
0	0.00	0.000	0.000	0.000	0.000	0.000	
600	2.93	2.920	2.910	2.911	2.914	-0.020	

Quality Criteria: ± 0.25m/s for ws ≤ 5m/s

Input (rpm)	Input (m/s)	DAS (m/s)	DAS (m/s)	DAS (m/s)	avg	Difference (m/s)	Difference (%)
1300	6.36	6.154	6.086	6.203	6.148		-3.293
2300	11.25	11.103	11.123	11.133	11.120		-1.132
4000	19.56	19.355	19.306	19.326	19.329		-1.181
7000	34.23	33.457	33.986	34.075	33.839		-1.141

Quality Criteria: ± 5% for ws ≥ 5m/s

Propeller Torque (g/cm): 1 Quality Criteria: 1gm-cm

Horizontal Wind Direction
Instrument Manufacturer and Model: RM Young 05103

Degrees Reference	Degrees DAS	Degrees DAS	Degrees DAS	avg	Difference Degrees
0	1.290	1.577		1.434	1.434
5	5.853	5.877		5.865	0.865
45	45.342	45.342		45.342	0.342
90	89.204	89.204	89.204	89.204	-0.796
135	133.256	133.232	133.256	133.248	-1.752
180	178.813	178.742	178.676	178.744	-1.256
225	223.272	223.272	223.224	223.256	-1.744
270	268.784	268.758	268.734	268.759	-1.241
315	313.240	313.240	313.240	313.240	-1.760
355	354.163	354.139		354.151	-0.849
357	4.706	4.730		4.718	-352.282

Quality Criteria: ± 5 degrees

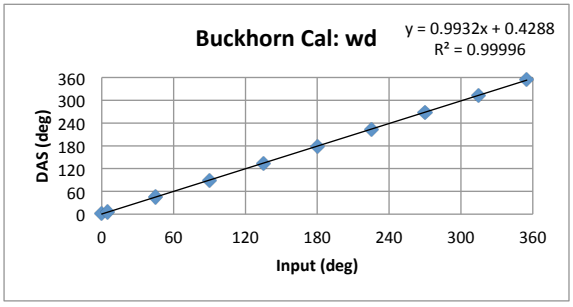
*Open circuit between 355 and 0

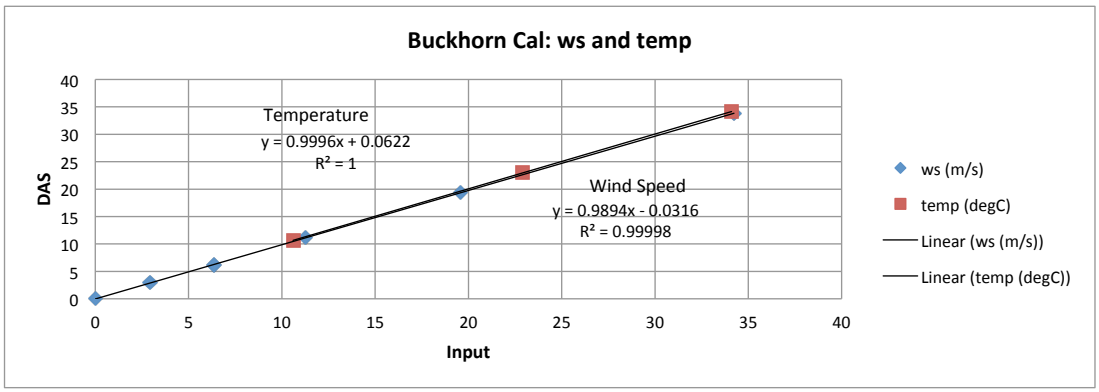
Ambient Temperature
Instrument manufacturer and Model: 107-L

Lower Limit (°C): -35
Upper Limit (°C): 50

	Input (°C)	DAS (°C)	Difference (°C)
Cold (near 0)	10.60	10.65	0.05
Warm (near 20)	22.90	22.97	0.07
Hot (near 40)	34.10	34.14	0.04

Quality Criteria: ± 1.0 (°C)





Site Name: Dry Piney **Date:** 4/11/12
Operator: BRE

Horizontal Wind Speed
Instrument Manufacturer and Model: RM Young 05103
Serial Number: 91816

Input (rpm)	Input (m/s)	DAS (m/s)	DAS (m/s)	DAS (m/s)	avg	Difference (m/s)	Difference (%)
0	0.00	0.000			0.000	0.000	
600	2.93	2.930	2.930	2.920	2.927	-0.007	
Quality Criteria: ± 0.25m/s for ws ≤ 5m/s							
Input (rpm)	**Input (m/s)**	**DAS (m/s)**	**DAS (m/s)**	**DAS (m/s)**	**avg**	**Difference (m/s)**	**Difference (%)**
1300	6.36	6.340	6.350	6.340	6.343		-0.215
2300	11.25	11.220	11.220	11.220	11.220		-0.240
4000	19.56	19.510	19.510	19.510	19.510		-0.256
7000	34.23	34.140	34.150	34.160	34.150		-0.234
Quality Criteria: ± 5% for ws ≥ 5m/s							

Propeller Torque (g/cm): 1 Quality Criteria: 1gm-cm

Horizontal Wind Direction
Instrument Manufacturer and Model: RM Young 05103

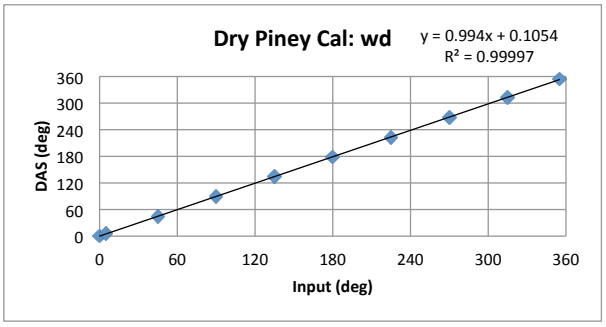
Degrees Reference	Degrees DAS	Degrees DAS	Degrees DAS	avg	Difference Degrees
0	0.430	0.360	0.380	0.390	0.390
5	5.620	5.790	5.720	5.710	0.710
45	44.920	44.970	44.950	44.947	-0.053
90	89.510	89.510	89.510	89.510	-0.490
135	133.800	133.800	133.800	133.800	-1.200
180	179.060	178.980	177.930	178.657	-1.343
225	223.250	223.010	223.010	223.090	-1.910
270	267.450	267.470	267.500	267.473	-2.527
315	313.380	313.400	313.400	313.393	-1.607
355	354.400	354.390	354.420	354.403	-0.597
357	4.280	4.250	4.280	4.270	-352.730
Quality Criteria: ± 5 degrees					

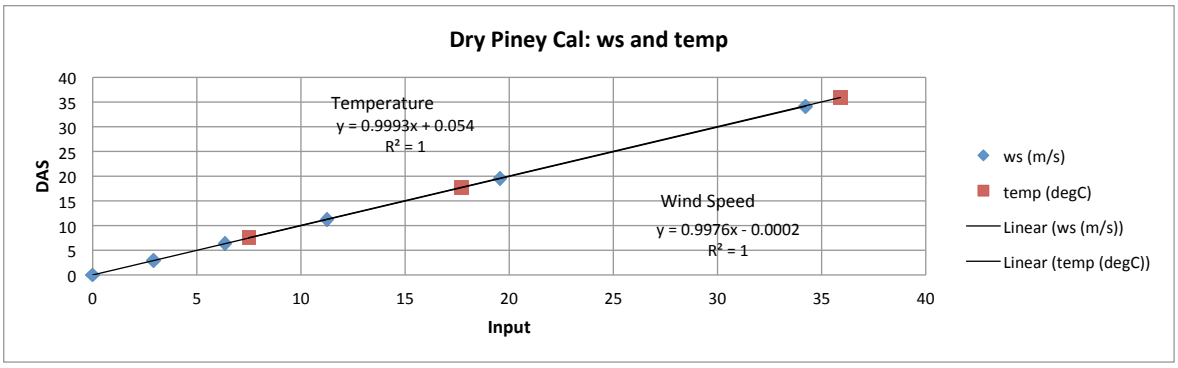
*Open circuit between 355 and 0

Ambient Temperature
Instrument manufacturer and Model: 107-L

Lower Limit (°C): -35
Upper Limit (°C): 50

	Input (°C)	DAS (°C)	Difference (°C)
Cold (near 0)	7.50	7.55	0.05
Warm (near 20)	17.70	17.74	0.04
Hot (near 40)	35.90	35.93	0.03
Quality Criteria: ± 1.0 (°C)			





Site Name: Burma **Date:** 4/9/12
Operator: BRE

Horizontal Wind Speed
Instrument Manufacturer and Model: RM Young 05305-AQ
Serial Number: 76868

Input (rpm)	Input (m/s)	DAS (m/s)	DAS (m/s)	DAS (m/s)	avg	Difference (m/s)	Difference (%)
0	0.00	0.000	0.000	0.000	0.000	0.000	
600	3.07	3.050	3.060	3.060	3.057	-0.009	

Quality Criteria: ± 0.25m/s for ws ≤ 5m/s

Input (rpm)	Input (m/s)	DAS (m/s)	DAS (m/s)	DAS (m/s)	avg	Difference (m/s)	Difference (%)
1300	6.64	6.620	6.600	6.590	6.603		-0.597
2300	11.75	11.680	11.690	11.670	11.680		-0.621
4000	20.44	20.380	20.390	20.380	20.383		-0.277
7000	35.77	35.660	35.670	35.670	35.667		-0.289

Quality Criteria: ± 5% for ws ≥ 5m/s

Propeller Torque (g/cm): 1 Quality Criteria: 1gm-cm

Horizontal Wind Direction
Instrument Manufacturer and Model: RM Young 05305-AQ

Degrees Reference	Degrees DAS	Degrees DAS	Degrees DAS	avg	Difference Degrees
0	0.060	0.140	0.150	0.117	0.117
5					
45	43.910	43.780	43.870	43.853	-1.147
90	89.870	89.950	89.980	89.933	-0.067
135	134.430	134.270	134.450	134.383	-0.617
180	179.460	179.420	179.450	179.443	-0.557
225	224.380	224.420	224.260	224.353	-0.647
270	269.100	269.130	269.130	269.120	-0.880
305	304.480	304.460	304.390	304.443	-0.557
355	354.420	354.410	354.450	354.427	-0.573
357	47.400	41.700	47.710	45.603	-311.397

Quality Criteria: ± 5 degrees

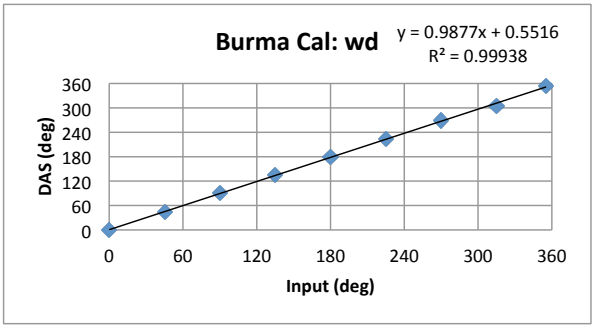
*Open circuit between 355 and 0

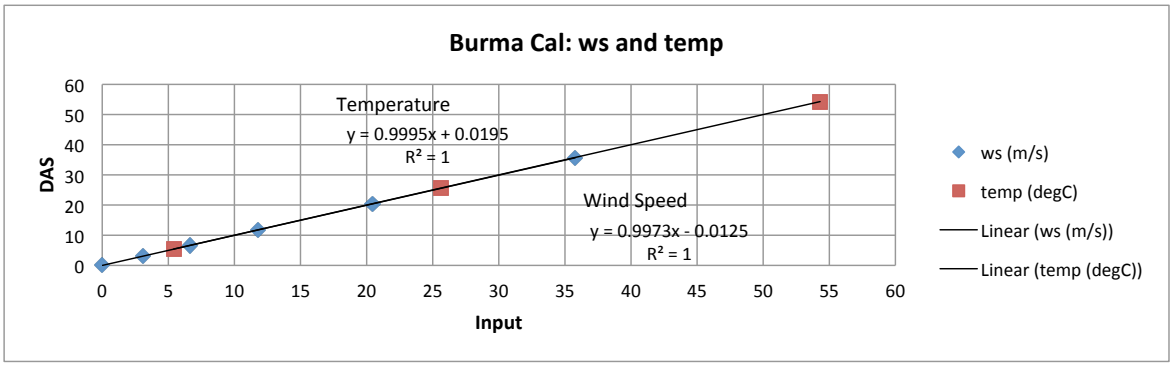
Ambient Temperature
Instrument manufacturer and Model: 109-L

Lower Limit (°C): -50
Upper Limit (°C): 70

	Input (°C)	DAS (°C)	Difference (°C)
Cold (near 0)	5.40	5.41	0.01
Warm (near 20)	25.60	25.62	0.02
Hot (near 40)	54.30	54.29	-0.01

Quality Criteria: ± 1.0 (°C)





Site Name: Speedway **Date:** 4/10/12
Operator: BRE

Horizontal Wind Speed
Instrument Manufacturer and Model: RM Young 05305-AQ
Serial Number: 76870

Input (rpm)	Input (m/s)	DAS (m/s)	DAS (m/s)	DAS (m/s)	avg	Difference (m/s)	Difference (%)
0	0.00	0.000	0.000	0.000	0.000	0.000	
600	3.07	3.060	3.050	3.060	3.057	-0.009	

Quality Criteria: ± 0.25m/s for ws ≤ 5m/s

Input (rpm)	Input (m/s)	DAS (m/s)	DAS (m/s)	DAS (m/s)	avg	Difference (m/s)	Difference (%)
1300	6.64	6.580	6.590	6.580	6.583		-0.898
2300	11.75	11.610	11.600	11.590	11.600		-1.302
4000	20.44	20.010	19.940	20.000	19.983		-2.234
7000	35.77	35.030	34.910	34.780	34.907		-2.414

Quality Criteria: ± 5% for ws ≥ 5m/s

Propeller Torque (g/cm): 1 Quality Criteria: 1gm-cm

Horizontal Wind Direction
Instrument Manufacturer and Model: RM Young 05305-AQ

Degrees Reference	Degrees DAS	Degrees DAS	Degrees DAS	avg	Difference Degrees
0	0.680	0.690	0.620	0.663	0.663
5	6.220	6.290	5.450	5.987	0.987
45	46.500	46.540	46.630	46.557	1.557
90	91.030	90.990	90.950	90.990	0.990
135	135.650	135.500	135.470	135.540	0.540
180	179.260	179.140	179.320	179.240	-0.760
225	223.860	223.830	223.850	223.847	-1.153
270	268.480	269.040	269.100	268.873	-1.127
315	313.580	313.860	313.730	313.723	-1.277
355	353.780	354.100	354.050	353.977	-1.023
357	15.240	15.210	15.250	15.233	-341.767

Quality Criteria: ± 5 degrees

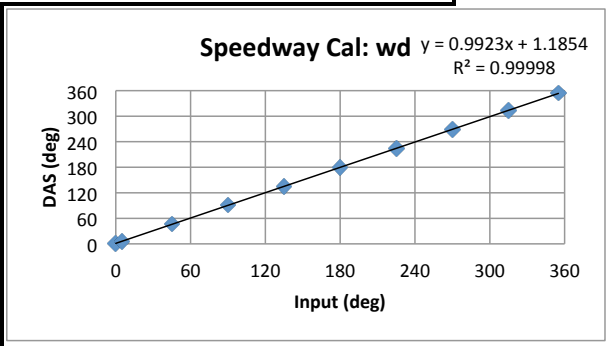
*Open circuit between 355 and 0

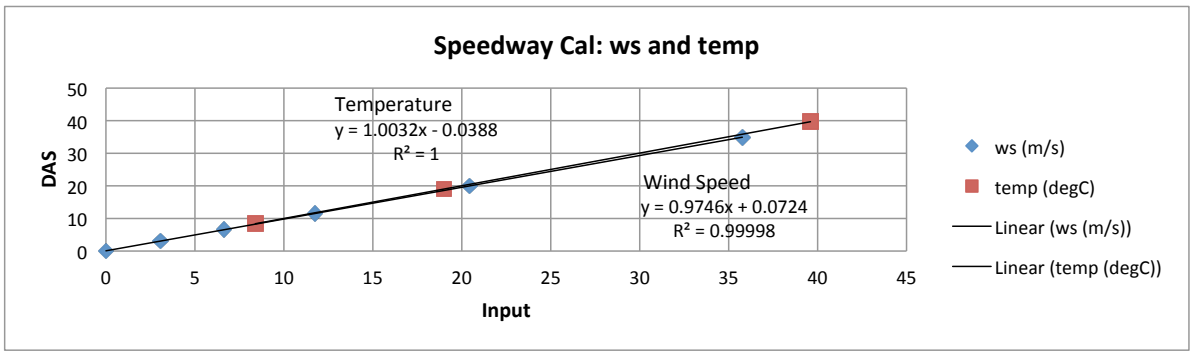
Ambient Temperature
Instrument manufacturer and Model: 109-L

Lower Limit (°C): -50
Upper Limit (°C): 70

	Input (°C)	DAS (°C)	Difference (°C)
Cold (near 0)	8.40	8.39	-0.01
Warm (near 20)	19.00	19.02	0.02
Hot (near 40)	39.60	39.69	0.09

Quality Criteria: ± 1.0 (°C)





Site Name: Two Rivers **Date:** 4/10/12
Operator: BRE

Horizontal Wind Speed
Instrument Manufacturer and Model: RM Young 05305-AQ
Serial Number: 76875

Input (rpm)	Input (m/s)	DAS (m/s)	DAS (m/s)	DAS (m/s)	avg	Difference (m/s)	Difference (%)
0	0.00	0.000	0.000	0.000	0.000	0.000	
600	3.07	3.060	3.060	3.060	3.060	-0.006	

Quality Criteria: ± 0.25m/s for ws ≤ 5m/s

Input (rpm)	Input (m/s)	DAS (m/s)	DAS (m/s)	DAS (m/s)	avg	Difference (m/s)	Difference (%)
1300	6.64	6.630	6.630	6.630	6.630		-0.196
2300	11.75	11.710	11.710	11.700	11.707		-0.394
4000	20.44	20.370	20.360	20.360	20.363		-0.375
7000	35.77	35.670	35.640	35.640	35.650		-0.335

Quality Criteria: ± 5% for ws ≥ 5m/s

Propeller Torque (g/cm): 1 Quality Criteria: 1gm-cm

Horizontal Wind Direction
Instrument Manufacturer and Model: RM Young 05305-AQ

Degrees Reference	Degrees DAS	Degrees DAS	Degrees DAS	avg	Difference Degrees
0	0.090	0.070	0.120	0.093	0.093
5	5.640	5.600	5.740	5.660	0.660
45	46.150	46.060	46.050	46.087	1.087
90	89.900	89.880	89.910	89.897	-0.103
135	133.110	133.020	133.110	133.080	-1.920
180	177.040	177.210	177.250	177.167	-2.833
225	222.500	222.510	222.390	222.467	-2.533
270	266.700	266.840	266.830	266.790	-3.210
315	311.460	311.450	311.440	311.450	-3.550
355	352.760	352.820	352.810	352.797	-2.203
357	354.480	354.480	354.400	354.453	-2.547

Quality Criteria: ± 5 degrees

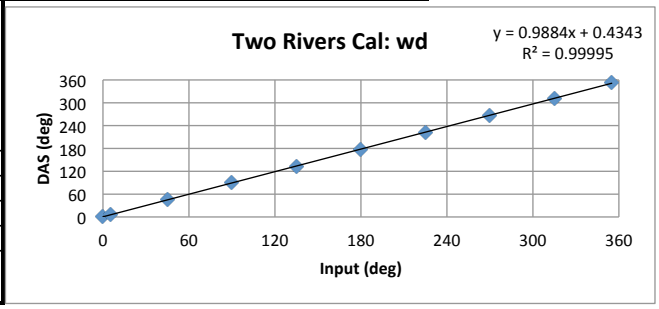
*Open circuit between 355 and 0

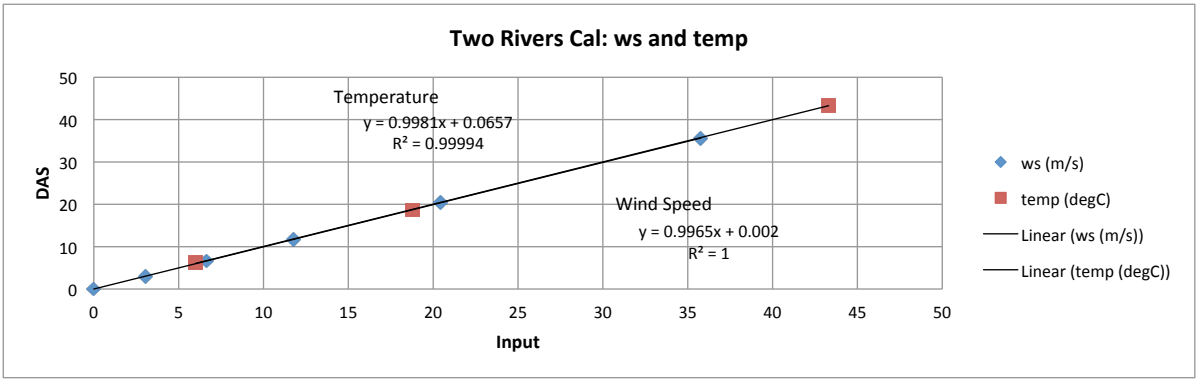
Ambient Temperature
Instrument manufacturer and Model: 109-L

Lower Limit (°C): -50
Upper Limit (°C): 70

	Input (°C)	DAS (°C)	Difference (°C)
Cold (near 0)	6.00	6.16	0.16
Warm (near 20)	18.80	18.67	-0.13
Hot (near 40)	43.30	43.34	0.04

Quality Criteria: ± 1.0 (°C)





Site Name: Riverside **Date:** 4/9/12
Operator: BRE

Horizontal Wind Speed
Instrument Manufacturer and Model: RM Young 05103
Serial Number:

Input (rpm)	Input (m/s)	DAS (m/s)	DAS (m/s)	DAS (m/s)	avg	Difference (m/s)	Difference (%)
0	0.00	0.000	0.000	0.000	0.000	0.000	
600	2.93	2.930	2.950	2.930	2.937	0.003	

Quality Criteria: ± 0.25m/s for ws ≤ 5m/s

Input (rpm)	Input (m/s)	DAS (m/s)	DAS (m/s)	DAS (m/s)	avg	Difference (m/s)	Difference (%)
1300	6.36	6.341	6.330	6.341	6.337		-0.309
2300	11.25	11.211	11.201	11.192	11.201		-0.406
4000	19.56	19.482	19.472	19.472	19.475		-0.433
7000	34.23	34.114	34.104	34.184	34.134		-0.280

Quality Criteria: ± 5% for ws ≥ 5m/s

Propeller Torque (g/cm): 1 Quality Criteria: 1gm-cm

Horizontal Wind Direction
Instrument Manufacturer and Model: RM Young 05103

Degrees Reference	Degrees DAS	Degrees DAS	Degrees DAS	avg	Difference Degrees
0	0.048	0.048	0.048	0.048	0.048
5	4.410	4.490	4.440	4.447	-0.553
45	44.730	44.730	44.730	44.730	-0.270
90	89.550	89.600	89.570	89.573	-0.427
135	134.340	134.710	134.750	134.600	-0.400
180	179.460	179.930	179.860	179.750	-0.250
225	224.440	224.560	224.560	224.520	-0.480
270	267.580	267.580	267.580	267.580	-2.420
315	312.550	312.580	312.550	312.560	-2.440
355	353.280	353.210	353.190	353.227	-1.773
357	354.500	354.500	354.500	354.500	-2.500

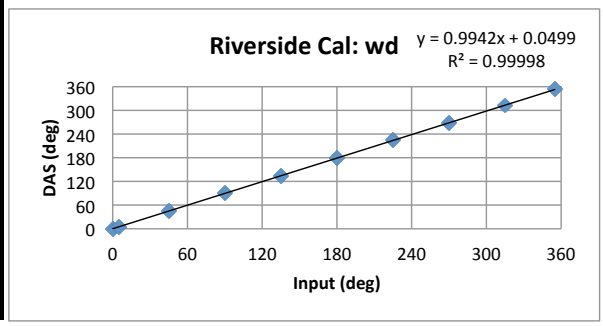
Quality Criteria: ± 5 degrees
*Open circuit between 355 and 0

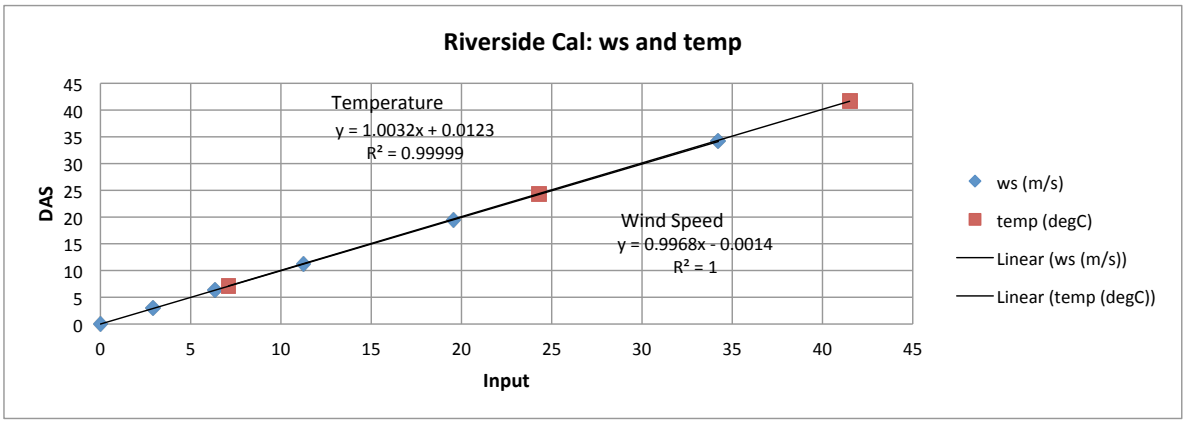
Ambient Temperature
Instrument manufacturer and Model: 107-L

Lower Limit (°C): -35
Upper Limit (°C): 50

	Input (°C)	DAS (°C)	Difference (°C)
Cold (near 0)	7.10	7.16	0.06
Warm (near 20)	24.30	24.34	0.04
Hot (near 40)	41.50	41.67	0.17

Quality Criteria: ± 1.0 (°C)





Site Name: Warren Bridge **Date:** 4/10/12
Operator: BRE

Horizontal Wind Speed
Instrument Manufacturer and Model: RM Young 05103
Serial Number: 91811

Input (rpm)	Input (m/s)	DAS (m/s)	DAS (m/s)	DAS (m/s)	avg	Difference (m/s)	Difference (%)
0	0.00	0.000	0.000	0.000	0.000	0.000	
600	2.93	2.920	2.911	2.920	2.917	-0.017	

Quality Criteria: ± 0.25m/s for ws ≤ 5m/s

Input (rpm)	Input (m/s)	DAS (m/s)	DAS (m/s)	DAS (m/s)	avg	Difference (m/s)	Difference (%)
1300	6.36	5.645	6.311	6.311	6.089		-4.216
2300	11.25	11.133	11.143	11.133	11.136		-0.984
4000	19.56	19.139	19.365	19.335	19.280		-1.433
7000	34.23	32.742	33.977	33.967	33.562		-1.952

Quality Criteria: ± 5% for ws ≥ 5m/s

Propeller Torque (g/cm): 1 Quality Criteria: 1gm-cm

Horizontal Wind Direction
Instrument Manufacturer and Model: RM Young 05103

Degrees Reference	Degrees DAS	Degrees DAS	Degrees DAS	avg	Difference Degrees
0	0.484	0.387	0.387	0.419	0.419
5	5.706	5.561	5.754	5.674	0.674
45	45.407	45.238	45.310	45.318	0.318
90	90.137	90.089	89.799	90.008	0.008
135	133.683	133.610	133.586	133.626	-1.374
180	178.292	178.195	177.929	178.139	-1.861
225	222.490	222.393	222.780	222.554	-2.446
270	268.236	268.139	268.163	268.179	-1.821
315	313.981	313.764	313.981	313.909	-1.091
355	354.504	354.601	354.529	354.545	-0.455
357	4.086	354.456	18.545	125.696	-231.304

Quality Criteria: ± 5 degrees

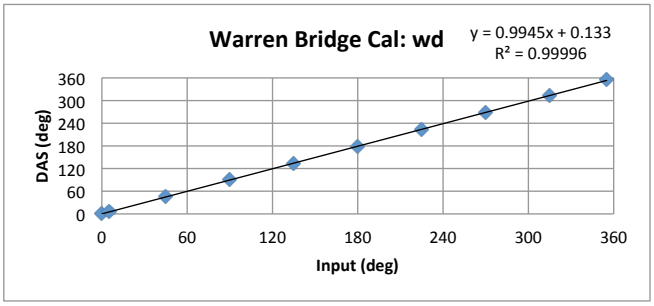
*Open circuit between 355 and 0

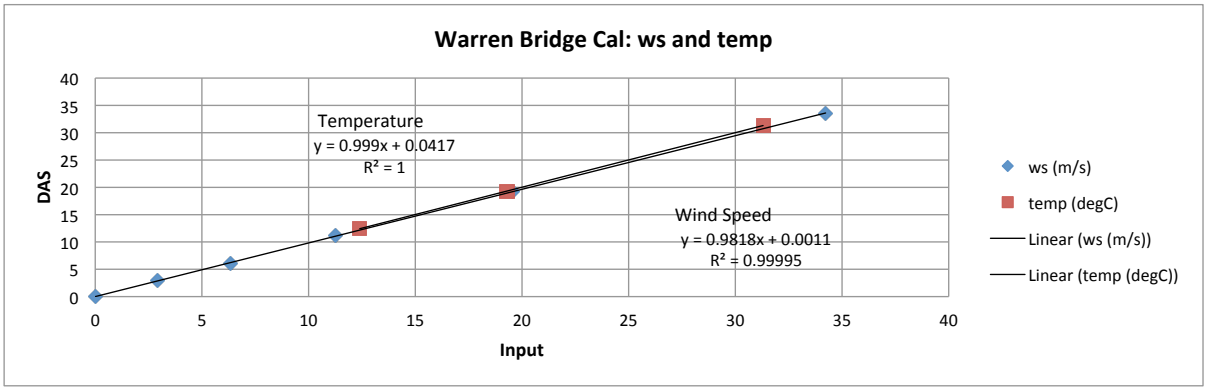
Ambient Temperature
Instrument manufacturer and Model: 107-L

Lower Limit (°C) -35
Upper Limit (°C) 50

	Input (°C)	DAS (°C)	Difference (°C)
Cold (near 0)	12.40	12.43	0.03
Warm (near 20)	19.30	19.32	0.02
Hot (near 40)	31.30	31.31	0.01

Quality Criteria: ± 1.0 (°C)





Site Name: Cottonwood Creek **Date:** 4/11/12
Operator: BRE

Horizontal Wind Speed
Instrument Manufacturer and Model: RM Young 05305-AQ
Serial Number:

Input (rpm)	Input (m/s)	DAS (m/s)	DAS (m/s)	DAS (m/s)	avg	Difference (m/s)	Difference (%)
0	0.00	0.000	0.000	0.000	0.000	0.000	
600	3.07	3.060	3.050	3.060	3.057	-0.009	
Quality Criteria: ± 0.25m/s for ws ≤ 5m/s							
Input (rpm)	**Input (m/s)**	**DAS (m/s)**	**DAS (m/s)**	**DAS (m/s)**	**avg**	**Difference (m/s)**	**Difference (%)**
1300	6.64	6.640	6.640	6.630	6.637		-0.095
2300	11.75	11.740	11.740	11.720	11.733		-0.167
4000	20.44	20.400	20.390	20.400	20.397		-0.212
7000	35.77	35.690	35.690	35.700	35.693		-0.214
Quality Criteria: ± 5% for ws ≥ 5m/s							

Propeller Torque (g/cm): 1 Quality Criteria: 1gm-cm

Horizontal Wind Direction
Instrument Manufacturer and Model: RM Young 05305-AQ

Degrees Reference	Degrees DAS	Degrees DAS	Degrees DAS	avg	Difference Degrees
0	2.570	2.570	2.610	2.583	2.583
5	8.250	8.230	8.250	8.243	3.243
45	47.570	47.540	47.570	47.560	2.560
90	91.350	91.310	91.290	91.317	1.317
135	134.560	134.630	134.700	134.630	-0.370
180	179.010	178.970	178.950	178.977	-1.023
225	223.390	223.980	223.900	223.757	-1.243
270	268.460	268.480	268.500	268.480	-1.520
315	313.980	313.990	314.030	314.000	-1.000
355	353.750	353.810	353.810	353.790	-1.210
357	20.160	20.310	20.270	20.247	-336.753

Quality Criteria: ± 5 degrees

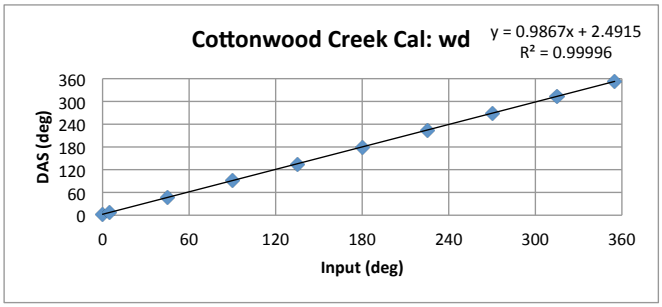
*Open circuit between 355 and 0

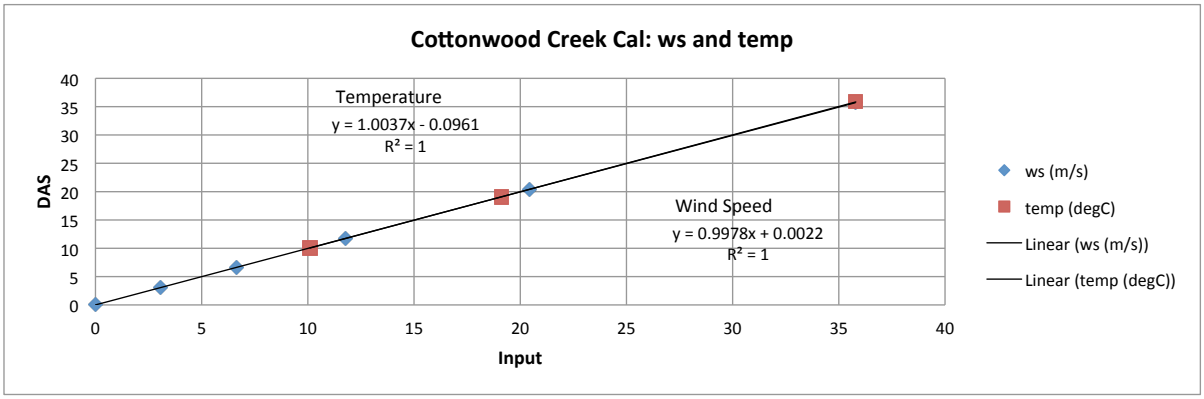
Ambient Temperature
Instrument manufacturer and Model: 109-L

Lower Limit (°C): -50
Upper Limit (°C): 70

	Input (°C)	DAS (°C)	Difference (°C)
Cold (near 0)	10.10	10.05	-0.05
Warm (near 20)	19.10	19.06	-0.04
Hot (near 40)	35.80	35.84	0.04

Quality Criteria: ± 1.0 (°C)





Site Name: Trapper's Point **Date:** 4/10/12
Operator: BRE

Horizontal Wind Speed
Instrument Manufacturer and Model: RM Young 05305-AQ
Serial Number:

Input (rpm)	Input (m/s)	DAS (m/s)	DAS (m/s)	DAS (m/s)	avg	Difference (m/s)	Difference (%)
0	0.00	0.000	0.000	0.000	0.000	0.000	
600	3.07	3.060	3.050	3.060	3.057	-0.009	

Quality Criteria: ± 0.25m/s for ws ≤ 5m/s

Input (rpm)	Input (m/s)	DAS (m/s)	DAS (m/s)	DAS (m/s)	avg	Difference (m/s)	Difference (%)
1300	6.64	6.630	6.640	6.630	6.633		-0.146
2300	11.75	11.850	11.720	11.720	11.763		0.088
4000	20.44	20.210	20.390	20.390	20.330		-0.538
7000	35.77	36.150	35.680	35.670	35.833		0.177

Quality Criteria: ± 5% for ws ≥ 5m/s

Propeller Torque (g/cm): 1 Quality Criteria: 1gm-cm

Horizontal Wind Direction
Instrument Manufacturer and Model: RM Young 05305-AQ

Degrees Reference	Degrees DAS	Degrees DAS	Degrees DAS	avg	Difference Degrees
0	1.210	1.120	0.930	1.087	1.087
5	6.160	6.440	6.550	6.383	1.383
45	45.150	45.900	45.870	45.640	0.640
90	89.710	89.870	89.870	89.817	-0.183
135	134.310	134.360	134.100	134.257	-0.743
180	178.680	178.870	178.730	178.760	-1.240
225	223.280	223.450	223.240	223.323	-1.677
270	268.320	268.600	268.740	268.553	-1.447
315	314.040	314.030	314.070	314.047	-0.953
355	354.320	354.350	354.570	354.413	-0.587
357	16.150	16.120	16.220	16.163	-340.837

Quality Criteria: ± 5 degrees

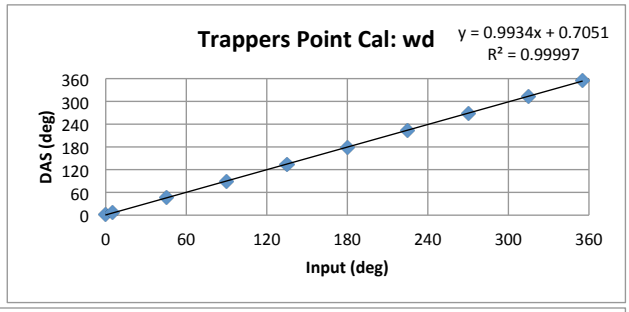
*Open circuit between 355 and 0

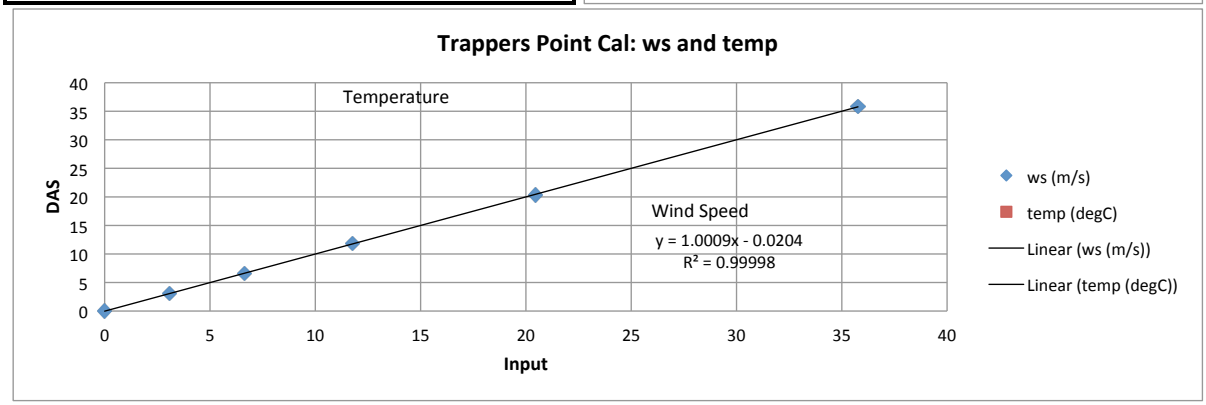
Ambient Temperature
Instrument manufacturer and Model:

Lower Limit (°C): -50
Upper Limit (°C): 70

	Input (°C)	DAS (°C)	Difference (°C)
Cold (near 0)			0.00
Warm (near 20)			0.00
Hot (near 40)			0.00

Quality Criteria: ± 1.0 (°C)





Site Name: Mesa **Date:** 4/11/12
Operator: BRE

Horizontal Wind Speed
Instrument Manufacturer and Model: RM Young 05103
Serial Number:

Input (rpm)	Input (m/s)	DAS (m/s)	DAS (m/s)	DAS (m/s)	avg	Difference (m/s)	Difference (%)
0	0.00	0.000	0.000	0.000	0.000	0.000	
600	2.93	2.930	2.930	2.920	2.927	-0.007	
Quality Criteria: ± 0.25m/s for ws ≤ 5m/s							
Input (rpm)	**Input (m/s)**	**DAS (m/s)**	**DAS (m/s)**	**DAS (m/s)**	**avg**	**Difference (m/s)**	**Difference (%)**
1300	6.36	6.340	6.330	6.340	6.337		-0.320
2300	11.25	11.190	11.190	11.170	11.183		-0.566
4000	19.56	19.470	19.390	19.390	19.417		-0.733
7000	34.23	34.000	33.980	33.980	33.987		-0.711
Quality Criteria: ± 5% for ws ≥ 5m/s							

Propeller Torque (g/cm): 1 Quality Criteria: 1gm-cm

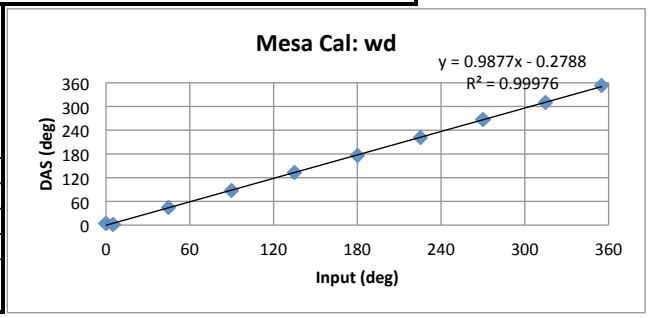
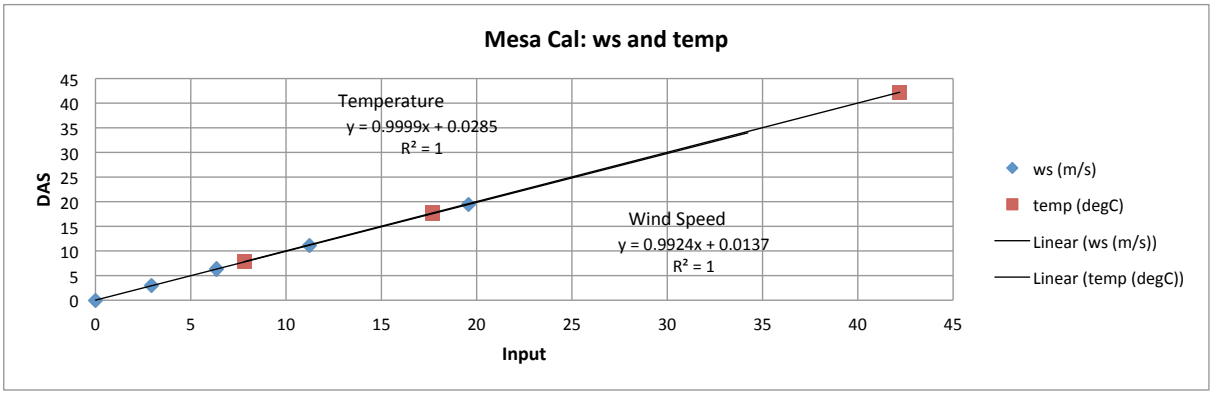
Horizontal Wind Direction
Instrument Manufacturer and Model: RM Young 05103

Degrees Reference	Degrees DAS	Degrees DAS	Degrees DAS	avg	Difference Degrees
0	4.180	4.150	4.180	4.170	4.170
5	2.100	2.100	2.000	2.067	-2.933
45	43.560	43.540	43.540	43.547	-1.453
90	88.880	88.880	88.200	88.653	-1.347
135	132.470	132.400	132.400	132.423	-2.577
180	178.360	177.010	173.790	176.387	-3.613
225	221.060	221.090	221.060	221.070	-3.930
270	266.360	266.310	266.310	266.327	-3.673
315	310.190	310.190	310.190	310.190	-4.810
355	352.510	352.510	352.510	352.510	-2.490
357	354.360	354.360	354.360	354.360	-2.640

Quality Criteria: ± 5 degrees
*Open circuit between 355 and 0

Ambient Temperature
Instrument manufacturer and Model: 107-L

Lower Limit (°C): -35
Upper Limit (°C): 50

	Input (°C)	DAS (°C)	Difference (°C)
Cold (near 0)	7.80	7.84	0.04
Warm (near 20)	17.70	17.71	0.01
Hot (near 40)	42.20	42.23	0.03

Quality Criteria: ± 1.0 (°C)